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How do mindfulness and compassion programs improve mental health and well-being? The role of attentional processing of emotional information

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ABSTRACT

Background and objectives: Although the benefits of Meditation-Based Programs are well documented, the mechanisms underlying these benefits have not been fully elucidated. Therefore, we examined whether: (1) formal training in mindfulness and compassion meditation modifies the distribution of attentional resources towards emotional information; and (2) whether changes in attentional processing of emotional information after the meditation programs mediate the improvements in psychological distress, emotion regulation, and well-being.

Methods: A sample of 103 participants enrolled in the study: 36 in the mindfulness program (MBSR), 30 in the compassion program (CCT), and 37 in the no-intervention comparison group (CG). The assessment before and after the programs included the completion of an emotional Attentional Blink task (AB) together with self-report measures of psychological distress, emotion regulation, and well-being.

Results: MBSR and CCT reduced similarly the AB deficit, whereas no changes occurred in the CG. This AB reduction was found for the different emotional and non-emotional stimuli (i.e., negative, positive, and neutral), showing a significant disengagement from first-target emotions and significant accessibility of second-target emotions to consciousness. The effects of both meditation programs on the psychological measures were mediated by changes in the AB and emotion regulation skills.

Limitations: Due to our naturalistic design in a real-world community setting, random assignment of participants was not feasible.

Conclusions: Meditation may promote more flexible and balanced attention to emotional information, which may be a key transdiagnostic mechanism underlying its benefits on emotional distress and well-being.

1. Introduction

An important reason for the rising popularity of meditation in the West is the well-validated Meditation-Based Programs (MBPs; Creswell, 2017). Numerous MBPs have been developed for reducing psychological distress and promoting well-being. Although meditation was not originally developed to treat mental disorders (Davidson & Dahl, 2018), meta-analytic evidence suggests that MBPs are a promising approach for a wide range of psychological problems (Wielgosz et al., 2019). In clinical populations, MBPs outperform no treatment, treatment as usual, and active control conditions, showing similar results as evidence-based treatments across different psychological disorders (Goldberg et al., 2018, 2021; Hedman-Lagerlöf et al., 2018). Furthermore, trials assessing MBPs in non-clinical populations also show improvements in psychological distress, stress, anxiety, depression, and wellbeing (Galante et al., 2021). For all the above, some MBPs have been listed as evidence-based treatments in prestigious clinical guidelines (National Institute for Health and Care Excellence, 2009).

Although the benefits of MBPs have been well documented, the mechanisms mediating these benefits remain insufficiently elucidated (Van Dam et al., 2018). Fortunately, there is a rising interest in the mechanisms of meditation practice (Baminiwatta & Solangaarachchi, 2021). MBPs target a set of transdiagnostic mechanisms common to different psychopathologies (Greeson et al., 2014), such as attentional

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control, emotional regulation, cognitive flexibility, or acceptance. Theoretical and empirical models highlight selected mechanisms of meditation, including the interaction between biological and psychological variables (Gu et al., 2015; Hölzel et al., 2011; Lim et al., 2015; Tang et al., 2015; Vago & Silbersweig, 2012; van der Velden et al., 2015).

Attending to the present moment is a core component of most mindfulness definitions (e.g., Bishop et al., 2004; Shapiro et al., 2006) and its training is an essential component of meditation practices (Dahl & Davidson, 2019; Wallace, 2006). Accordingly, attention regulation is one of the mechanisms that has received more research interest in recent years (Chiesa et al., 2011; Hölzel et al., 2011; Malinowski, 2013; Tang et al., 2015). In general, studies have found that meditation is associated with more accurate, efficient, and flexible attentional processing (Hodgins & Adair, 2010). Based on the general framework of cognitive theories (Beck, 1987) and cognitive models of meditation (Bishop et al., 2004), clinical researchers have hypothesized that changes in attentional biases may be one of the key mechanisms underlying the benefits of meditation practice in emotional distress and wellbeing (Davis & Thompson, 2015; Ford et al., 2021; Garland et al., 2015; Kiken & Shook, 2012; Roca & Vazquez, 2020; Vago & Silbersweig, 2012). Meditation aims to promote a more flexible and non-judgmental attentional toward one's experiences (Bishop et al., 2004; Kabat-Zinn, 1994), engaging with negative, positive, and neutral stimuli equally, rather than avoiding or focusing on certain experiences (Brown et al., 2007; Garland et al., 2015). Therefore, meditation should encourage less biased and more balanced attention to emotional information (Roca & Vazquez, 2020). A recent review of the literature suggests that mindfulness meditation is associated with diminished negative cognitive biases across different measures (i.e., self-reported and behavioral measures), different samples (i.e., clinical, and non-clinical), and different study designs (i.e., correlational, quasi-experimental, and experimental) (Ford et al., 2021). Furthermore, some studies show that reductions in cognitive biases mediate the relationship between meditation practice and psychological distress (Ford et al., 2021; Ford & Shook, 2019).

Data from behavioral tasks and neuroimaging studies have shown that meditation practice modulates the attentional processing of emotional information (Bi et al., 2021; Magalhaes et al., 2018). De Raedt et al. (2012) found that a standardized mindfulness intervention, compared to a control group, showed reduced facilitation of attention for negative information and reduced inhibition of attention for positive information among individuals with recurrent major depression. Other studies using eye-tracking methods have found that meditation interventions significantly reduce the time looking at negative faces (Blanco et al., 2020; Pavlov et al., 2015), and reduce the pupillary dilation to negative stimuli relative to a control group (Vasquez-Rosati et al., 2017). Interestingly, a reduction of attentional biases towards negative stimuli has occurred in some medical conditions, such as fibromyalgia and chronic pain, after meditation interventions (Garland & Howard, 2013; Vago & Nakamura, 2011). Meditation has had similar effects on patients with alcohol dependence when they process addiction-related cues (Garland et al., 2011, 2012).

Taken together, these studies highlight the effects of meditation on attentional biases toward emotional information as a mechanism that may mediate the benefits of meditation practice on emotional distress and well-being. One important additional issue is whether changes in attentional biases are associated with different types of meditation. After the surge of research on Mindfulness-Based Programs, the science of meditation is moving beyond its mindfulness-centered focus (Davidson & Dahl, 2018; Van Dam et al., 2018), including other types of meditation practices (e.g., compassion meditation). In the present study, we compared the mechanisms of mindfulness and compassion meditation, as the latter has shown significant benefits in clinical and non-clinical interventions to reduce psychological suffering and improve well-being (Kirby et al., 2017; Seppälä et al., 2017). Whereas mindfulness is the intentional self-regulation of attention to the present moment without judgment (Kabat-Zinn, 2013), compassion constitutes the feeling that arises when witnessing one's and another's suffering, together with the motivation to alleviate the suffering (Goetz et al., 2010; Strauss et al., 2016). Empirical studies suggest that certain outcomes and mechanisms are shared by mindfulness and compassion practice, whereas others are specific to each practice (Brito-Pons et al., 2018; Roca et al., 2021; Singer & Engert, 2019). For instance, Desbordes et al. (2012) found that mindfulness and compassion programs produce different neurological changes in response to emotional stimuli: the mindfulness group showed an overall decrease in amygdala activation when viewing images of any valence (i.e., negative, positive, and neutral), the compassion group showed an increase in amygdala activation in response to negative images. Similarly, mindfulness and compassion programs both improve early automatic stages of emotional processing by increasing the flexibility of resource allocation (Roca & Vazquez, 2020).

In the present study, we examined: (1) the differences between mindfulness and compassion meditation in the distribution of attentional resources towards emotional information as compared to a no-intervention comparison group; and (2) whether changes in attentional processing of emotional information after the meditation programs mediate the improvements in psychological distress, emotional regulation, and well-being. For this purpose, we developed a variation of the Attentional Blink paradigm (using negative, positive, and neutral faces) that was completed before and after the meditation programs, together with self-reported measures of psychological distress, emotion regulation, and well-being. Based on extant literature (e.g., Desbordes et al., 2012; Roca & Vazquez, 2020), we hypothesized that the practice of both mindfulness and compassion meditation would improve the distribution of attentional resources towards emotional information (i.e., reducing the Attentional Blink deficit) as compared to a comparison group. However, because of ambiguities in the literature (e.g., Blanco et al., 2020; Pavlov et al., 2015), we had little basis for predicting differential processing of emotional stimuli as a function of type of meditation. Regarding mediating mechanisms, we hypothesized that attentional changes would significantly mediate the positive outcomes of the programs. Based on previous models of the mechanisms of meditation practice (Chiesa et al., 2011; Hölzel et al., 2011; Malinowski, 2013; Tang et al., 2015), we also hypothesized that attentional changes would be a key component of the emotional regulation processes predicting psychological distress and well-being improvements.

2. Method

2.1. Participants

A 3-armed non-randomized naturalistic trial was conducted where participants were recruited from a community setting and voluntarily self-allocated either to MBSR or CCT program. A total of 103 participants enrolled in the study: 36 in MBSR, 30 in CCT, and 37 in a no-intervention comparison group (CG) (see Fig. 1). A precise description of the general participation attrition is presented in Fig. 1. Participants' mean age was 46.06 ($S.D. = 11.19$), 65.1% were women, 88% had university studies, 44.6% were married and 12% were unemployed. There were no significant differences among the three groups in age ($F_{(2, 84)} = 2.35, p > .05$), education ($\chi^2_{(4)} = 7.65, p > .05$), marital status ($\chi^2_{(10)} = 12.91, p > .05$), employment status ($\chi^2_{(14)} = 11.68, p > .05$), mental health diagnosis ($\chi^2_{(2)} = 2.71, p > .05$), physical illness diagnosis ($\chi^2_{(2)} = 0.93, p > .05$), the mean number of months of previous meditation practice ($F_{(2, 41)} = 0.82, p > .05$), and current meditation practice in minutes ($F_{(2, 27)} = 0.81, p > .05$). However, there were significant differences among the groups in gender ($\chi^2_{(2)} = 11.747, p < .05$); the CCT group had a higher percentage of women ($CCT_{women} = 92\%$) than did the other two groups ($MBSR_{women} = 57\%$; $GC_{women} = 50\%$).

Inclusion criteria were as follows: (1) normal or corrected-to-normal vision; (2) being 18 years old or above; (3) not having any current

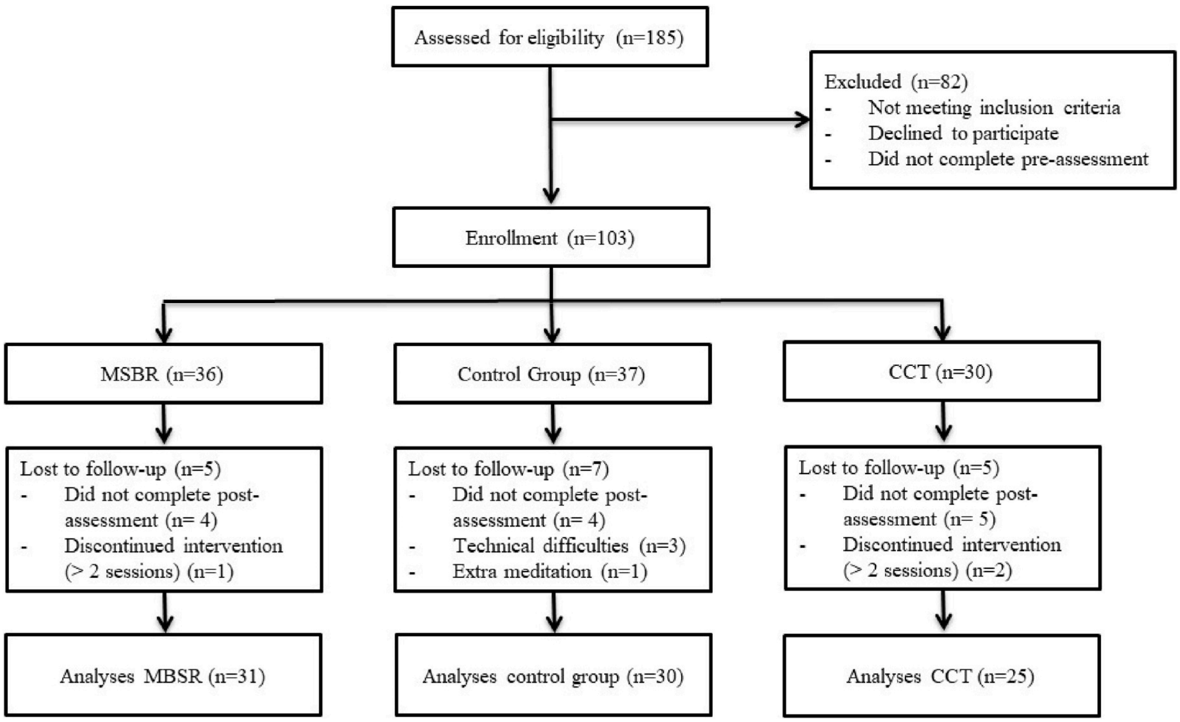

Fig. 1. Participation CONSORT diagram.

serious psychological disorder or substance use; and (4) having attended at least 6 of the 8 sessions (i.e., 75% of the program). G*Power (v. 3.0.10) was used to estimate the sample size required to test the mixed ANOVA. With an effect size of 0.25 for the psychological distress measures (Brito-Pons et al., 2018) and an alpha of .05, we would need at least a total of 88 participants to detect significant effects at 90% power. We finally selected about 20% more participants to compensate for expected attrition at post-assessment (Roca & Vazquez, 2020).[1]

2.2. Procedure

Participants from MBSR and CCT groups were recruited from a university-associated research center specializing in Mindfulness and Compassion-Based Programs, with more than ten years of previous experience offering standardized meditation programs in secular and health-related contexts. Participants were invited to join the study during the registration phase on the university's official website offering the programs, explaining that the study aimed to analyze the psychological effects of meditation practice. After being recruited for the study, participants filled out a brief online screening questionnaire on demographics and inclusion/exclusion criteria via the Qualtrics platform. To form the CG, we asked all participants from MBSR and CCT groups to recruit other participants (friends, relatives, or acquaintances) with similar sociodemographic characteristics (matched by age, gender and previous meditation experience). The only requirement for inclusion in the CG, other than completing the pre- and post-assessments, was not to attend any standardized meditation training during the eight weeks of the study. Eligible individuals received information about the study phases and gave their informed consent before their inclusion in the study.

The procedure included the completion of the online assessment together with an experimental session (i.e., emotional AB task) twice, one during the week before starting the 8-week program (i.e., pre-assessment) and the other during the week after its completion (post-assessment). In the case of the CG, participants attended the two experimental sessions with eight weeks between them. At the end of the last assessment session, all participants were debriefed on the goals of the study and were given a complimentary individualized report on their pre-post changes in the questionnaires used in the program. The research was approved by the university ethics committee before participant recruitment (Ref 2016/17--016) and was registered at ClinicalTrial.org (NCT03920241). This report is part of a larger study, part of which has been published elsewhere (Roca et al., 2021).

3. Measures

3.1. Attentional blink task

Participants underwent a valid variant of the Emotional Attentional Blink task (AB) that analyzes attentional changes toward emotional stimuli following meditation practice (Roca & Vazquez, 2020). E-prime v.2 software (Psychology Software Tools, Inc., Pittsburgh, PA) was used to program the task (see further technical details in Supplementary Materials). The AB is a Rapid Serial Visual Presentation paradigm that measures the temporal limitations of attention. In the AB task, visual stimuli are briefly presented in rapid succession. Two of the items in the trial sequence are targets (i.e., T1 and T2) and the rest are distractors. The proximity of the second target relative to the first one is manipulated (i.e., T1-T2 lag), as a function of the number of intervening distractors between them. Typically, the first target is correctly identified; however, the second target is poorly identified when it appears between 200 and 500 ms after the first one. This time-lapse effect is known as the "attentional blink" or "refractory period". Therefore, the AB effect is defined as a reduction in the accuracy of detecting a second target (T2) when it is presented between 200 and 500 ms after a first target (T1; Raymond et al., 1992).

Our AB task followed a 3 (T1 emotion: angry, happy, and neutral) x 3

[1] We also computed a second power analysis for the attentional changes: in a previous study comparing attentional changes between mindfulness and compassion programs, Roca and Vazquez (2020) found an effect size of 0.19 for the interaction, which results in a sample size of 93 participants to detect effects at 90% power, which is below the number of participants in the present study.

(T2 emotion: angry, happy, and neutral) x 2 (T1-T2 lag: 2 and 6) x 3 (group: MBSR, CCT, and CG) x 2 (Time: pre, and post-intervention) experimental design. Following MacLean and Arnell's (2012) technical recommendations, half of the trials were programmed within the attentional blink period (i.e., one distractor between the targets; Lag = 2; SOA = 200 ms), whereas the other half was configured outside the attentional blink period (i.e., five distractors between the targets; Lag = 6; SOA = 600 ms). The internal consistency of the AB task was α = 0.91.

Fig. 2 shows the Emotional AB task trial sequence (see further details of the AB task in Supplementary Materials). Target stimuli were randomly sampled and all combinations of T1 and T2 emotions were presented equally often. Participants' task was to identify the emotions of T1 and T2 faces, ignoring the scrambled faces. At the end of each trial, two consecutive questions were asked: "Which emotion did you see in the first/second face?" Participants responded by using a keyboard with four response alternatives: "neutral", "angry", "happy", or "I haven't seen any faces." The response keys were balanced across participants (i.e., z, x, n, m). Following Stein et al., (2009) recommendations, the main dependent variable for the emotional AB was T2 accuracy (i.e., emotion identification) upon having correctly identified T1 emotion (i.e., having placed attentional resources on the first target identification, how long does it take for participants to recover their attentional resources so that they can identify the second target emotion?). Furthermore, to modulate the AB effect across the different task conditions, we calculated the AB magnitude as the change scores in T2 performance at short relative to long lags (i.e., T2 ACC lag 6 – lag 2) for each T1 and T2 emotion (MacLean & Arnell, 2012).

3.2. Self-report measures

The online assessment included measures of psychological distress, emotion regulation, and well-being. The Depression Anxiety Stress Scales (DASS-21, Lovibond & Lovibond, 1995) were used to measure the symptoms of depression, anxiety, and stress. The Difficulties in Emotion Regulation Scale (DERS, Gratz & Roemer, 2004) assessed emotion regulation difficulties and the Pemberton Happiness Index (PHI, Hervás & Vázquez, 2013) measured psychological well-being. In the current study, the internal consistency was α = 0.90 for DASS-21 (stress: 0.81; depression: 0.90; anxiety: 0.77), α = 0.94 for DERS, and α = 0.93 for PHI.

3.3. Data analysis plan

Data pre-processing was conducted, including incorrect response tendencies in the AB task and imputation in the self-reported measures (see further details in Supplementary Materials). The data analysis plan was conducted following four successive steps.

First, to test the differences between groups in the attentional processing of emotional information, a 3 (T1 Emotion: neutral, happy, angry) x 3 (T2 Emotion: neutral, happy, angry) x 2 (T1-T2 Lag: 2, and 6) x 3 (Group: MBSR, CCT, and CG) x 2 (Time: pre-post program) mixed ANOVA was carried out on T2 emotion identification accuracy (upon having correctly identified T1 emotion). For all the analyses: (a) ANOVA assumptions were tested at baseline, by using the Shapiro-Wilk test to assess normality, Levene's test to assess homoscedasticity, non-parametric Runs test to assess independence, and Greenhouse-Geisser correction when the assumption of sphericity was violated; (b) effect sizes were calculated for ANOVA interactions (η_p^2) (c) power analysis (i.e., 1-β); was carried out for each significant effect; and (d) post-hoc analyses of means were done by using pairwise Bonferroni corrected comparisons.

Considering the study hypotheses (i.e., no changes in AB were expected in the CG, whereas a reduction in the AB effect was expected in the MBSR and CCT) and the AB paradigm properties (i.e., by definition the AB is a lag-dependent effect), four ANOVA interactions were analyzed: 1) a significant Lag x Time × Group interaction would indicate a "lag-dependent effect" or "standard AB effect", in other words, AB reduction after the meditation programs with no changes in the CG; 2) a significant T1 Emotion x Lag x Time × Group interaction would indicate a "lag as a function of T1 emotion" or "disengagement of emotional stimuli", in other words, a reduction of the attentional resources captured by T1 emotion after the meditation programs and no changes in the CG; 3) a significant T2 Emotion x Lag x Time × Group interaction would indicate a "lag as a function of T2 emotion" or "emotional AB effect", in other words, an increase in the accessibility of the T2 emotion to awareness after the meditation programs while no changes in CG; and 4) a significant T1 Emotion x T2 Emotion x Lag x Time x Group full interaction would be indicative of a "lag as a function of T1-T2 emotions combination" or "complex emotional AB effect", in other words, AB differences between mindfulness and compassion programs depending on T1-T2 emotion combinations with no changes in CG.

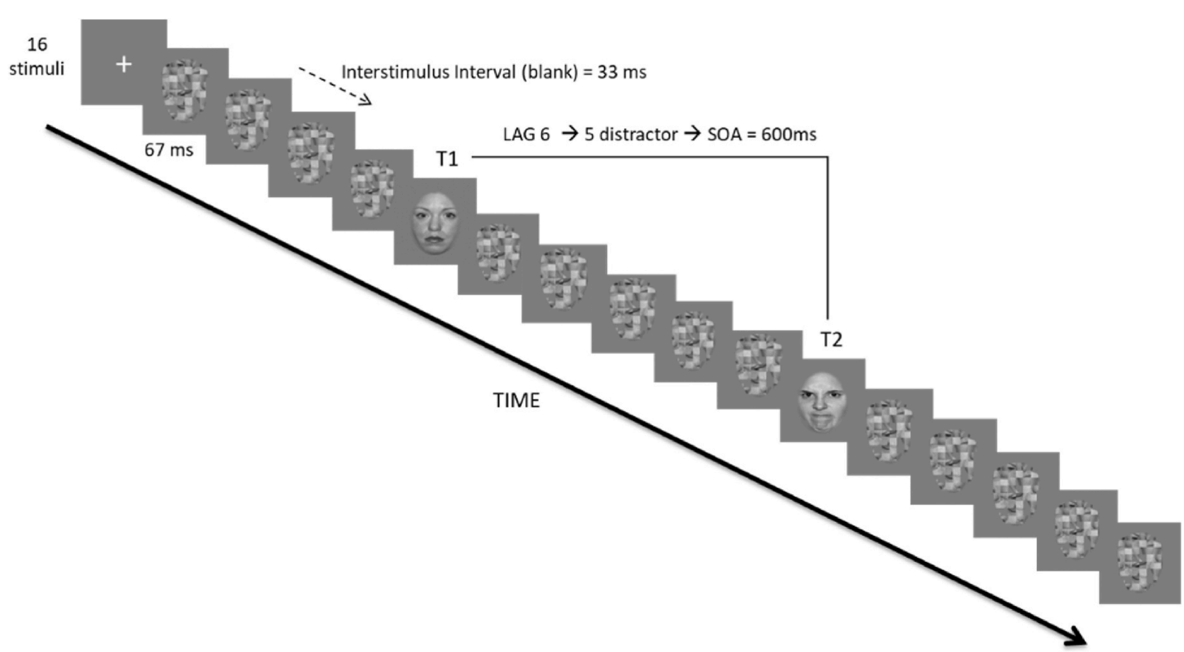

Fig. 2. Emotional AB task trial sequence. An example of the lag 6 trial is presented.

Second, single mediation analyses were performed to examine whether the attentional improvements mediated the efficacy of the meditation programs on psychological distress (i.e., stress, anxiety, and depression), emotional regulation, and well-being. Mediations were conducted on simple change scores (i.e., post – pre), which is a common practice to explore mechanisms of action in psychological interventions (e.g., Roca et al., 2021; Schotanus-Dijkstra et al., 2019), by using the group as the predictor "X" (i.e., meditation vs control), self-reported measures as the outcomes "Y" (i.e., psychological distress, emotional regulation, and well-being), and the attentional changes in the AB magnitude as the mediator "M" (i.e., T2 accuracy lag 6 – lag 2).

Third, considering the results of previous single mediation models, we computed serial mediations to test whether the effects of meditation programs on psychological distress and well-being were mediated by both, attentional improvements, and emotion regulation changes. Specifically, we tested whether the meditation programs (X) predict the attentional changes (M1) and emotional regulation changes (M2), and these, in turn, predict the psychological distress (i.e., stress, anxiety, and depression) and well-being changes (Y). Unstandardized regression coefficients (*b*) were computed for all the paths, as well as R^2 and indirect effects (c-path).

Finally, moderation analyses were carried out to examine whether the relationship between the meditation programs (X) and the attentional changes (Y) was moderated by different baseline variables (W), including age, sex, education, months of previous meditation practice, and current meditation practice in minutes. SPSS 25 was used for all analyses, and we used PROCESS macro v. 3.4 to perform mediation analyses following Hayes's (2018) technical recommendations. The data are available at https://github.com/nirakara-lab/Attentional-Blink-mechanisms-in-meditation.

4. Results

4.1. Emotional attentional blink task

First, a significant Lag x Time × Group interaction ($F_{(2, 83)} = 8.55$, $p = .000$, $\eta^2_{\text{partial}} = .17$; 1-$\beta$ = 0.96) supported the existence of a lag-dependent effect. The means and standard deviations of the AB task are presented in Table 1. There was a significant reduction of the standard AB deficit after both meditation programs (MBSR and CCT) whereas no changes occurred in the CG. Regarding short lag 2, pairwise Bonferroni corrected comparisons indicated that both MBSR and CCT significantly increased the emotion identification accuracy after the programs (i.e., they reduced the standard AB effect for lag 2), whereas no changes occurred in the CG (see Fig. 3). Regarding long lag 6, post hoc comparisons showed that only MBSR significantly increased the accuracy for lag 6 after the program, whereas no changes were found in the CCT and CG.

Second, a significant T1 Emotion x Lag x Time × Group interaction ($F_{(4, 166)} = 4.39$, $p = .002$, $\eta^2_{\text{partial}} = .10$; 1-$\beta$ = 0.93) supported the existence of a lag as a function of T1 emotion. There was a significant disengagement of T1 emotions after both meditation programs (MBSR and CCT), which illustrates a reduction of the emotional AB after completing them; no changes occurred in the CG. Regarding the short lag 2, pairwise Bonferroni corrected comparisons indicated that both MBSR and CCT significantly increased the emotion identification accuracy after angry, happy, and neutral T1 (i.e., they reduced the AB effect for lag 2 after negative, positive, and neutral T1 stimuli); no changes occurred in the CG for any of the emotions (see Supplementary Fig. 1). Regarding the long lag 6, post hoc comparisons showed that only MBSR significantly increased the accuracy after a neutral T1, whereas no changes occurred in the CCT and CG.

Third, a marginally significant T2 Emotion x Lag x Time × Group interaction was found ($F_{(4, 166)} = 2.40$, $p = .05$, $\eta^2_{\text{partial}} = .06$; 1-$\beta$ = 0.68), which provided partial support for the existence of a lag as a function of T2 emotion. There was significant accessibility of T2 emotions to

Table 1
T2 accuracy after having correctly identified T1. Means (Standard deviation). Note: MBSR = Mindfulness-Based Stress Reduction; CCT= Compassion Cultivation Training; CG = comparison group.

		MBSR						CCT						CG					
		Pre – T2			Post – T2			Pre – T2			Post – T2			Pre – T2			Post – T2		
		Angry	Happy	Neutral	Angry	Happy	Neutral	Angry	Happy	Neutral	Angry	Happy	Neutral	Angry	Happy	Neutral	Angry	Happy	Neutral
Lag 2 T1	**Angry**	.63	.63	.48	.75	.75	.66	.74	.72	.55	.79	.86	.66	.57	.63	.39	.59	.64	.39
		(.23)	(.25)	(.28)	(.26)	(.28)	(.28)	(.15)	(.16)	(.19)	(.26)	(.13)	(.19)	(.31)	(.26)	(.22)	(.29)	(.25)	(.27)
	Happy	.80	.67	.59	.84	.79	.75	.84	.74	.70	.93	.83	.82	.70	.61	.46	.74	.63	.50
		(.20)	(.27)	(.29)	(.16)	(.27)	(.28)	(.10)	(.18)	(.18)	(.10)	(.20)	(.15)	(.23)	(.28)	(.27)	(.21)	(.26)	(.29)
	Neutral	.81	.72	.61	.85	.78	.74	.88	.82	.67	.91	.89	.74	.75	.72	.54	.78	.75	.49
		(.17)	(.25)	(.31)	(.20)	(.25)	(.31)	(.11)	(.12)	(.20)	(.11)	(.12)	(.20)	(.22)	(.19)	(.28)	(.22)	(.23)	(.30)
Lag 6 T2	**Angry**	.92	.92	.95	.94	.94	.95	.93	.95	.93	.91	.94	.94	.87	.89	.85	.92	.91	.90
		(.08)	(.13)	(.06)	(.07)	(.11)	(.06)	(.11)	(.08)	(.09)	(.18)	(.07)	(.07)	(.14)	(.12)	(.17)	(.09)	(.10)	(.11)
	Happy	.95	.93	.93	.96	.97	.93	.97	.92	.95	.95	.93	.96	.95	.91	.91	.93	.95	.91
		(.04)	(.09)	(.11)	(.05)	(.05)	(.06)	(.04)	(.10)	(.05)	(.07)	(.18)	(.05)	(.05)	(.09)	(.11)	(.07)	(.07)	(.09)
	Neutral	.92	.93	.91	.96	.94	.97	.97	.95	.94	.96	.95	.91	.88	.91	.91	.91	.93	.90
		(.08)	(.14)	(.09)	(.06)	(.07)	(.04)	(.04)	(.05)	(.08)	(.05)	(.05)	(.16)	(.11)	(.09)	(.12)	(.10)	(.07)	(.12)

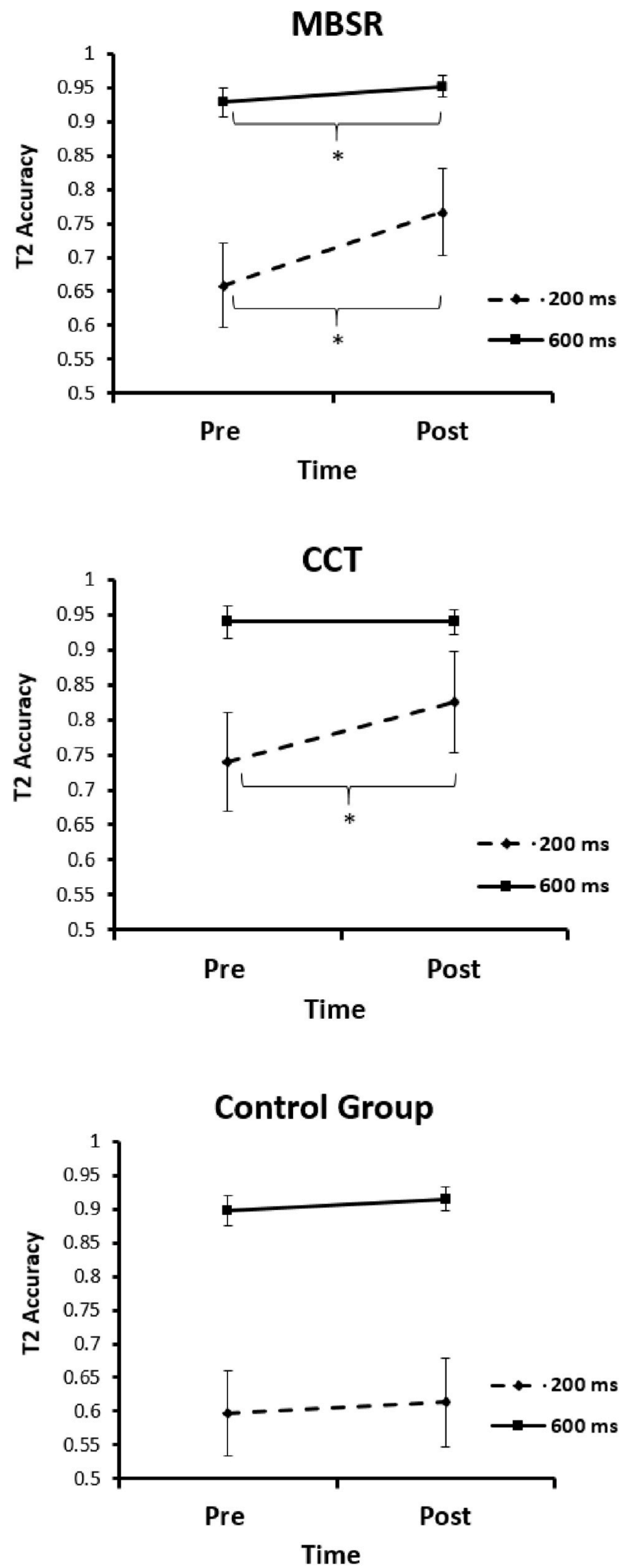

Fig. 3. Lag-dependent effect or "standard AB effect". Average T2 emotion identification accuracy for MBSR (top panel), CCT (medium panel), and CG (bottom panel). Results are presented separately before and after the programs for each interval between targets (i.e., lag 200 and 600 ms). The error bars represent the standard error for each 95% confidence interval. Note: $^*p < .01$.

consciousness after the meditation programs (MBSR and CCT), whereas no changes occurred in the CG. The effect was illustrated by a reduction of the emotional AB deficit after the meditation programs. Regarding short lag 2, pairwise Bonferroni corrected comparisons indicated that both MBSR and CCT significantly increased the emotion identification accuracy for angry, happy, and neutral T2 (i.e., a significant reduction of the AB effect for negative, positive, and neutral T2 stimuli at lag 2), whereas no changes occurred in the CG for any of the emotions (see Supplementary Fig. 2). Regarding long lag 6, post hoc comparisons showed that no significant changes occurred at post-program in any of the groups.

Finally, the full interaction T1 Emotion x T2 Emotion x Lag x Time × Group interaction was nonsignificant ($F_{(8,\ 332)} = 0.92$, $p = .49$), inconsistent with the lag as a function of T1-T2 emotions combination. The reduction of the AB deficit after the meditation programs was unrelated to the different combinations of T1 and T2 emotions.

4.2. Attentional improvements as mediators of psychological outcomes (single mediation)

After confirming that MBSR and CCT showed similar attentional changes in the AB task, we decided to combine both groups in a "meditation group" to compare its effects with the "non-meditation" comparison group. Studying a combined meditation group is congruent with the relative lack of results supporting the differences between different meditation, as we stated in the introduction. Mediation analyses were performed by including attentional improvements as mediators of changes in psychological distress (i.e., stress, anxiety, and depression), emotional regulation, and well-being (see Supplementary Fig. 3). Attentional improvements did not mediate the relationship between meditation and psychological distress changes, showing nonsignificant indirect effects on stress ($b = .04$; $s.e. = 0.33$; 95% CI -0.66, 0.67]), anxiety ($b = -0.25$; $s.e. = 0.35$; 95% CI -0.93, 0.48]), and depression ($b = 0.01$; $s.e. = 0.39$; 95% CI [-0.81, 0.77]). However, the effects of meditation programs on emotion regulation and well-being were entirely mediated by attentional improvements, showing a significant indirect effect on emotion regulation ($b = -2.06$; $s.e. = 1.04$; 95% CI [−4.28, −0.21]), and well-being ($b = 2.28$; $s.e. = 1.07$; 95% CI [0.31, 4.59]). Therefore, the association between the meditation programs and improvements in emotion regulation skills and well-being were entirely mediated by reductions in the blink deficit in meditators compared to control participants. The total model explained 12% of the variance in emotion regulation and 11% in well-being.

4.3. Attentional improvements and emotion regulation as mediators of psychological distress and well-being (serial mediation)

Serial mediations were computed to test whether the effects of meditation programs on psychological distress and well-being were mediated by both attentional and emotion regulation changes (see Fig. 4). The indirect effect of meditation programs predicting attentional improvements which, in turn, predicts emotional regulation changes, and then predicts psychological distress, was statistically significant for the three measures: stress ($b = -0.16$; $s.e. = 0.12$; 95% CI [−0.46, −0.03]), anxiety ($b = -0.34$; $s.e. = 0.18$; 95% CI [−0.73, −0.03]), and depression ($b = -0.09$; $s.e. = 0.05$; 95% CI [−0.20, −0.01]). Furthermore, the indirect effect of meditation programs predicting attentional improvements, which in turn predicts emotional regulation changes, and finally predicts psychological well-being was also statistically significant ($b = 0.63$; $s.e. = 0.48$; 95% CI [0.01, 1.83]). These results suggest that the relationship between the meditation programs and the improvements in psychological distress and well-being were entirely mediated by reductions in the attentional blink deficit, which, in turn, predicts emotional regulation improvements. The total model explained 37% of the variance of anxiety changes, followed by 22% in depression, 20% in well-being, and 8% in the case of stress.

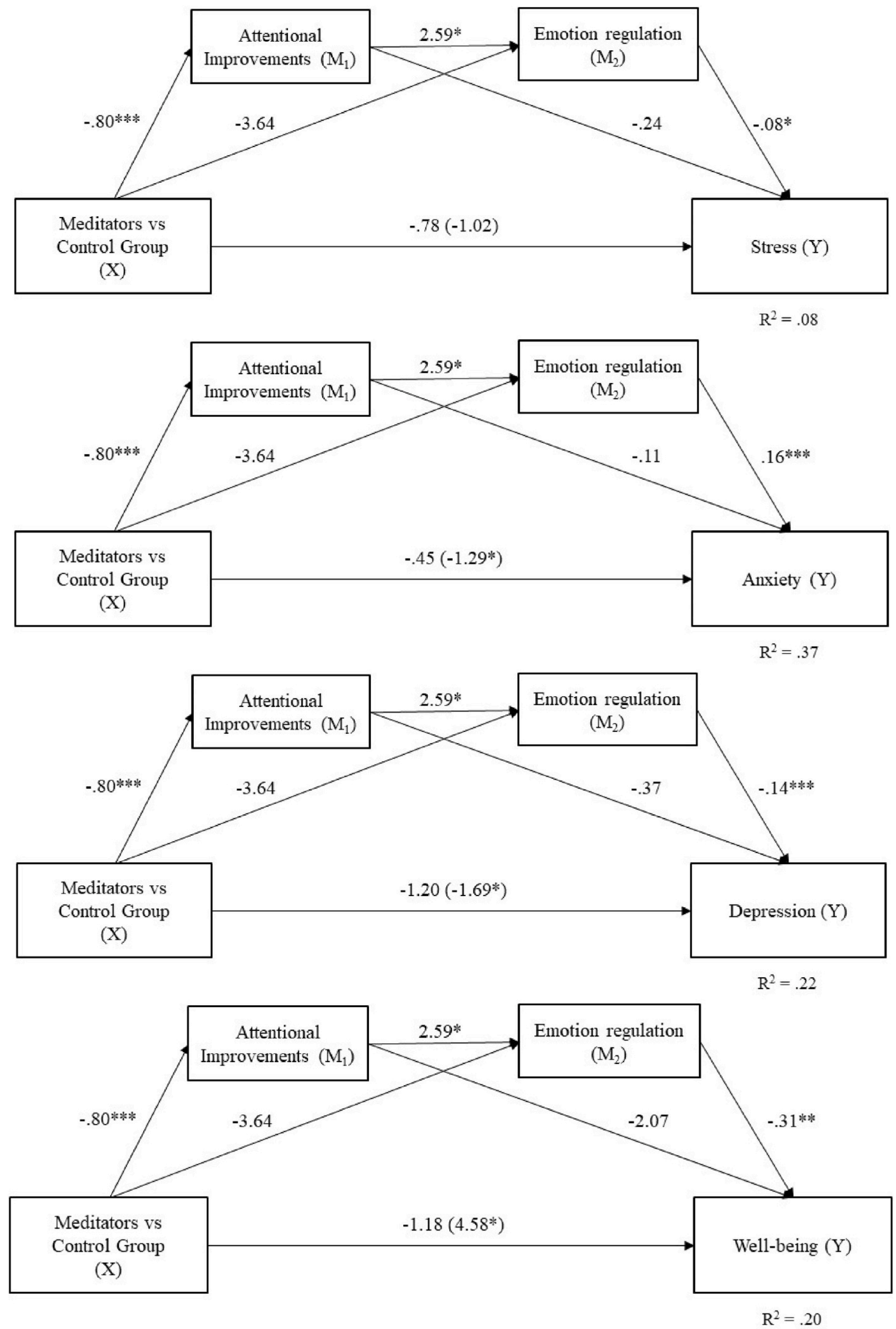

Fig. 4. Serial mediations with attentional improvements and emotion regulation as mediators of the changes in psychological distress and well-being. The paths show the unstandardized regression coefficients. The *c-path* is provided in brackets. Note: $^{*}p < .05$; $^{**}p < .01$; and $^{***}p < .001$.

5. Discussion

The general aim of the study was to examine whether standardized mindfulness and compassion meditation programs could change the distribution of attentional resources towards emotional information as compared to a no-intervention comparison group in a variation of the emotional Attentional Blink task. Moreover, we explored whether these attentional changes mediate improvements in psychological distress, emotional regulation, and well-being.

First, we examined whether mindfulness and compassion programs modulate the attentional processing of emotional information. Analyses of variance showed that both MBSR and CCT similarly reduced the attentional blink deficit, whereas no changes occurred in the CG. There was a significant increase in emotion identification accuracy after mindfulness and compassion programs, with a large effect size. Meditators improved the identification of both the first and the second targets, even when the second target was presented less than half a second after the first one (i.e., refractory period). These results are in line with previous findings (Slagter et al., 2007; van Vugt & Slagter, 2014), suggesting that even highly structured and brief 8-week mindfulness and compassion programs increase the flexibility of resource allocation in the early stages of attentional processing (Isbel et al., 2020; Malinowski, 2013). Our results add to previous evidence showing that meditation practice improves attentional processing (Hodgins & Adair, 2010; Sumantry & Stewart, 2021; Yakobi et al., 2021; Zainal & Newman, 2020), reducing the propensity to "get stuck" on certain stimuli and improving the allocation of attentional resources.

Importantly, this attentional blink reduction after the meditation programs occurred for all emotions (i.e., negative, positive, and neutral). The analysis of lag as a function of T1 and T2 emotions showed a double disengagement-engagement effect: on one hand, a significant disengagement of T1 emotions and, on the other hand, a significant accessibility of T2 emotions to consciousness. No changes occurred in the CG for any emotion. These results contrast with those obtained in other studies with participants from the general population with no formal meditation training, where emotional T1 stimuli (compared to neutral ones) capture our attentional resources, thereby increasing the AB deficit (e.g., de Jong et al., 2010; Maratos, 2011), while emotional T2 stimuli reach consciousness more easily than neutral T2 stimuli, hence reducing the AB deficit (e.g., Maratos et al., 2008; Milders et al., 2006). However, our results suggest that mindfulness and compassion programs may improve the disengagement of attentional resources from the T1 emotion, freeing up attentional resources that are then available for the processing of the T2 emotion. These results extend previous findings in contemplative sciences (Makowski et al., 2019; Roca & Vazquez, 2020), suggesting that meditation may promote more flexible and balanced attention to emotional information by favoring a more equal engagement with negative, positive, and neutral stimuli, rather than avoiding or focusing on certain stimuli or experiences. Our results are congruent with neuroimaging studies showing that mindfulness modulates the neural responses to emotional stimuli in the early stages of emotional processing, reducing brain reactivity (Brown et al., 2013; Taylor et al., 2011) and cardiovascular reactivity (Pavlov et al., 2015) to emotional information (both pleasant and unpleasant). The improvements in the balance of emotional information processing in meditators might be interpreted as an indicator of equanimity, an even-minded mental state towards all experiences, regardless of their hedonic tone (Desbordes et al., 2015; Hadash et al., 2016). Meditators' learning goals are to be mindful of emotional and non-emotional experiences in the present moment, accepting them with a non-judgmental attitude, thereby reducing emotional and cognitive reactivity. In that sense, equanimity would be an important emotional regulation strategy in meditation, promoting less biased attention and faster recovery from emotional information. Thus, future studies explore the potential use and validity of our emotional variant of the AB task as an experimental measure of equanimity.

Taken together, these results highlight the potential effects of standardized mindfulness and compassion meditation programs on attentional biases toward emotional information (Blanco et al., 2020; De Raedt et al., 2012; Ford et al., 2021). In fact, engagement-disengagement difficulties when processing emotional information is among the key transdiagnostic factors associated with emotional disorders (Armstrong & Olatunji, 2012). Therefore, we examined whether attentional improvements would mediate the efficacy of the meditation programs on psychological distress, emotional regulation, and well-being. Single mediation analyses revealed that the improvements in emotion regulation skills and well-being were entirely mediated by reductions of the attentional blink deficit in meditators compared to control participants. However, attentional improvements did not mediate the changes in psychological distress (i.e., stress, anxiety, and depression). According to the Liverpool Mindfulness Model (Malinowski, 2013), the training of attentional skills is a catalyst for greater emotional and cognitive flexibility and regulation, which, in turn, results in additional positive outcomes, including better mental health and well-being. Thus, serial mediations were conducted to test the theoretical model that meditation programs improve mental health indicators via changes in attentional and emotional regulation. Our results supported this theoretical model for both reductions in psychological distress (i.e., stress, anxiety, and depression) and well-being improvements. There was a significant indirect effect of meditation programs predicting attentional improvements and emotional regulation changes, and finally predicting changes in mental health indicators. These results highlight the central role of attentional changes as the "entry door" for other psychological mechanisms involved in meditation practices (Chiesa et al., 2011; Holzel et al., 2011; Malinowski, 2013), including emotion regulation processes (Guendelman et al., 2017).

We found that both mindfulness and compassion programs similarly reduced the AB deficit, and only subtle differences emerged between these two active groups. Evidence suggests that there are common and specific effects and mechanisms in mindfulness and compassion standardized programs (Roca et al., 2021). Certainly, mindfulness is a keystone for other meditation practices and is formally practiced at the beginning of compassion programs. Similarly, compassion elements are implicitly taught in mindfulness programs (Neff & Dahm, 2015; Roca et al., 2021). Perhaps intensive 8-week programs are not enough to uncover genuine attentional differences between mindfulness and compassion meditation. Future longitudinal studies should explore whether these attentional changes vary over time as the person gains more experience, as well as dismantling and additive component studies (Bell et al., 2013).

Finally, moderators of attentional changes were also examined to clarify who benefits most from meditation programs. However, the effects of meditation programs on attentional blink were not significantly moderated by any of our variables. The relationship between meditation and attentional changes did not depend upon age, gender, education, the months of previous meditation practice, or the current meditation practice in minutes. Future studies should replicate our results with other meditation types (e.g., deconstructive practices), practice dosage (e.g., 8-week program vs meditation retreat), or different practice settings (e.g., meditation retreats, mobile apps).

Our results must be considered in light of some methodological limitations. Due to the naturalistic design of our trial, it was infeasible to randomly assign participants to the groups. However, non-randomized comparisons still have probative value to examine the relative effectiveness and mechanisms of meditation-based programs in real-world settings (Dimidjian & Segal, 2015). Furthermore, participants were not blind to the study conditions (although they were blind to the specific aims of the study and the AB task). Future studies should address these methodological limitations by using randomized designs to minimize the potential influence of self-selection bias, as well as active control conditions (MacCoon et al., 2012). Power analysis was computed to detect changes in the psychological measures, which could lead to the study being underpowered to detect group differences in the AB task. Another important limitation is that only pre- and post-measures were analyzed, we should be cautious about claiming causality in the results and long-term longitudinal studies are needed to analyze the maintenance of the changes over time. Furthermore, the use of change scores may involve some mathematical risks, such as decreased reliability (McNally, 2019). With regards to the sample characteristics, some baseline features may have affected the results, such as the high educational level, the use of a non-clinical sample, or the inclusion of participants with and without previous meditation experience (although our sample adequately reflects real characteristics of participants who attend meditation programs).

In sum, we believe that our study illuminates some key mechanisms mediating the beneficial impact of two popular meditation programs. As far as we know, this is the first study examining whether changes in attentional processing of emotional information after mindfulness and compassion standardized programs mediate the improvements in psychological variables, which may be a key transdiagnostic mechanism underlying its benefits on emotional distress and well-being. Meditation training is postulated as a feasible alternative to modify the attentional processing of emotional information, which is an important result considering the limited effectiveness of procedures like the Attentional Bias Modification (Cristea et al., 2015).

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CRediT authorship contribution statement

Pablo Roca: Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Conceptualization, Data curation. **Carmelo Vazquez:** Investigation, Methodology, Project administration, Supervision, Writing – review & editing, Conceptualization, Funding acquisition. **Gustavo Diez:** Funding acquisition, Project administration, Resources, Writing – review & editing. **Richard J. McNally:** Conceptualization, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

We have shared the link to our data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2023.101895.

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