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Dispositional mindfulness, alexithymia and sensory processing: Emerging insights from habituation of the acoustic startle reflex response

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ABSTRACT

There is growing evidence of beneficial effects of mindfulness developed through engaging in mindfulness training/practices on sensory and cognitive processing, emotion regulation and mental health. Mindfulness has also been conceptualised as a dispositional 'trait', i.e. the naturally-occurring ability of meditation-naïve individuals to display, in varying degree, a non-judgmental non-reactive present-moment awareness in everyday life. In this study we examined possible associations between dispositional mindfulness, alexithymia and sensory processing. Eye-blink startle responses to acoustic stimuli of varying intensity [90-dB or 100-dB over 70-dB (A) background] were assessed in 26 meditation-naïve adults (50 % men) using electromyographic recordings of the orbicularis muscle. All participants completed the Five Facet Mindfulness Questionnaire and the 20-item Toronto Alexithymia Scale. A negative association was found between dispositional mindfulness and alexithymia ($r = -0.513$). There was stronger startle habituation to 100-dB, compared to 90-dB probes. Stronger startle habituation (larger negative habitation slope values) to 100-dB probes was significantly associated with higher dispositional mindfulness ($r = -0.528$) and with lower alexithymia at trend level ($r = 0.333$). As indicated by commonality analysis, 10.6 % of explained variance in habituation (100-dB probes) was common to both alexithymia and mindfulness, 17.3 % was unique to mindfulness, but alexithymia made negligible unique contribution (0.5 %). These findings indicate similar startle habituation pattern in people with a high level of dispositional mindfulness to that reported previously by Antonova et al. (2015) in people with moderate mindfulness meditation practice intensity. Future studies should investigate the mechanisms, such as interoceptive awareness, that might underly these relationships.

1. Introduction

There is growing evidence for a positive impact of mindfulness developed through training ('cultivated' mindfulness) on sensory and cognitive processing (Chiesa et al., 2011; Gallant, 2016; Kumari et al., 2017), emotion regulation and mental health (reviews, Antonova et al., 2021; Goldberg et al., 2018; Keng et al., 2011; Li and Bressington, 2019; Mandal et al., 2011). There are early indications that mindfulness-based interventions can also reduce alexithymia (Norman et al., 2019) which is characterised by difficulty in expressing and understanding one's emotional state and an externally-oriented thinking style (Preece et al., 2017). In addition to cultivated mindfulness (Ivanovski and Malhi, 2007), mindfulness has also been conceptualised as a 'dispositional' personality trait, referring to the naturally-occurring tendency in meditation-naïve people to display, in varying degree, a non-judgmental and non-reactive present-moment awareness in everyday life (Brown and Ryan, 2003). In line with various documented benefits of cultivated mindfulness, dispositional mindfulness is found to correlate negatively with affective symptoms, including anxiety, depression and stress, in the general population (meta-analysis, Carpenter et al., 2019).

Mindfulness, as a state and trait, has been shown to be multifaceted (Baer et al., 2006, 2008) with five facets capturing distinct processes or skills that characterise mindfulness as a mode of relating to one's present-moment experiences, whether 'internal' (thoughts, feelings, sensations) or 'external' (objects of perception): (i) *observing* (i.e. noticing or attending to experiences), (ii) *describing* (expressing/

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labelling experiences in words), (iii) *acting with awareness* (attending to activities of the moment rather than running on automatic pilot), (iv) *non-judging* (refraining from evaluating experiences as pleasant or unpleasant); and (v) *non-reactivity* (allowing experiences to come and go without being caught up in them). These skills were found to be strengthened by mindfulness training in pre-to-post training evaluations (Baer et al., 2008; de Bruin et al., 2012; Wallmark et al., 2013), as well as to have positive associations with cognitive functioning and well-being, and negative associations with alexithymia and depression in correlational research (Baer et al., 2006; Baer et al., 2008; de Bruin et al., 2012). The exact cognitive mechanisms underlying these positive effects, however, are yet to be empirically established, and may vary according to particular style/s of mindfulness meditation practice (Lutz et al., 2015) or particular facets of mindfulness being displayed naturally in the case of meditation-naïve individuals (Himichi et al., 2021).

Startle response models may be particularly useful to further our understanding of the effects of mindfulness on sensory and information processing mechanisms (Antonova et al., 2015; Kumari et al., 2015). The startle reflex to acoustic probes is easily measurable in a human laboratory setting using an eye-blink, which is an automatic (involuntary) physiological response to startling stimuli, with the resulting data being free of culture-related context/influences and relatively immune to demand characteristics. In line with the potential utility of the startle reflex paradigm to advance neuroscientific study of mindfulness, our previous study (Antonova et al., 2015) yielded tentative evidence of reduced acoustic startle habituation in meditators with intensive practice routines (i.e., practicing for more than 1 h a day on average over the years of regular practice), consistent with the notion that mindfulness should foster openness to incoming stimulus, even if repetitive or aversive; there was, however, evidence of greater startle habituation in meditators with moderate practice.

Extending this line of enquiry to dispositional mindfulness, the present study examined associations between facets of dispositional mindfulness, as conceptualised by Baer et al. (2006), and sensory processing as indexed by the amplitude and habituation of the acoustic startle response. Given that the startle response is sensitive to parametric manipulations and increases with stimulus intensity (Blumenthal and Berg, 1986; Blumenthal et al., 2005), and that it may be more or less sensitive to individual differences at different intensity manipulations (Kumari et al., 1996), we included acoustic stimuli of both medium (90-dB) and high (100-dB) intensity. Based on our earlier observations (Antonova et al., 2015), we expected a positive association between dispositional mindfulness and habituation of the startle response, assuming a shared neurobiology between non-meditators with a high dispositional (naturally-occurring) mindfulness and meditators with moderate (rather than intense) practice. Furthermore, we sought to confirm previously reported negative associations between mindfulness and alexithymia (de Bruin et al., 2012), and tentatively hypothesised weaker habituation (i.e., an opposite pattern to that expected in relation to dispositional mindfulness) in association with a high level of alexithymia. Previous studies have consistently shown moderate positive correlations between self-reported alexithymia and depression (meta-analysis, Li et al., 2015), and also reported elevated blood pressure or hypertension in association with both alexithymia (Casagrande et al., 2019; Jula et al., 1999) and depression (e.g., Okajima et al., 2015). Given that both depression (Allen et al., 1999; Dichter and Tomarken, 2008; Kaviani et al., 2004) and hypertension (Shukla et al., 2020) are found to be associated with hypo-startling, we also explored and expected lower startle amplitude in association with a high level of alexithymia.

2. Materials and methods

2.1. Participants and design

The study involved 30 non-meditating healthy adults recruited from the general population. The inclusion criteria required all participants to be free from any hearing impairment, have normal/corrected vision, not diagnosed with neuropsychiatric disorders, not be on regular medication, not have a substance misuse past, and be non-smoking and not drinking >28 units of alcohol per week [1 unit = 1/2 pint of beer (285 mls) or 25 ml of spirits or 1 glass of wine], or >6 units of caffeinated beverage a day (all assessed with self-report). All included participants were assessed on a single occasion. The study used a correlation design. To examine the hypothesised association between higher dispositional mindfulness and stronger startle habituation ($p < 0.05$) with sufficient power (80 %) to detect correlation coefficient of at least 0.5, the minimum required sample size is 23 as determined using G*power3 (Faul et al., 2007). In absence of any direct data testing this association (the only previous study on this topic examined experienced meditators versus meditation-naïve individuals; Antonova et al., 2015), we arbitrarily chose a medium effect size of $r = 0.5$ (Cohen, 1992) to power the study, but recruited slightly more participants (n = 30) to ensure the minimum required final sample size. Of these 30 individuals, 26 individuals (13 males, 13 females; sex as determined at birth) provided usable psychophysiology and self-report data (1 participant excluded because of <70 % startle response probability, 1 participant excluded because of noisy EMG data, and 2 participants excluded due to incomplete self-report data), allowing us 80 % power to detect correlation coefficient of at least 0.467.

The study was approved by the college of Health, Medicine and Life Sciences ethics committee, Brunel University London. All participants provided written informed consent prior to taking part, and were compensated for their time and travel.

2.2. Self-report measures of dispositional mindfulness and alexithymia

For dispositional mindfulness, all participants completed the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006). Its five facets, as per Baer et al.'s model (2006; 2008) described earlier, are: (1) *observing* (e.g., "When I'm walking, I deliberately notice the sensations of my body moving."), (2) *describing* (e.g., "I'm good at finding words to describe my feelings."), (3) *acting with awareness* (e.g., "I find myself doing things without paying attention." with reverse scoring), (4) *non-judging* (e.g., "I tell myself I shouldn't be feeling the way that I am feeling.") and (5) *non-reactivity* (e.g. "I watch my feelings without getting lost in them."). It has 39 items in total (8 items each for *observing*, *describing*, *acting with awareness*, and *non-judging*, and 7 items for *non-reactivity* facet), with each item rated on a 5-point Likert scale ('never or very rarely', 'rarely', 'sometimes', 'often', 'very often' or 'always true'; scored 1 to 5). Higher scores indicate higher mindfulness. The FFMQ is currently one of the most frequently used measures of dispositional mindfulness. FFMQ scales have high internal consistency with Cronbach's alpha ranging from 0.75 to 0.93 (Baer et al., 2008; Christopher et al., 2012; Shallcross et al., 2020); Cronbach's alpha for the current sample ranged from 0.799 to 0.907). Since Baer et al. (2006, 2008) have advised against using the *observing* subscale in meditation-naïve samples (this facet appears to exist only in experienced meditators; e.g., Williams et al., 2014), we assessed dispositional mindfulness as the sum of the scores on the remaining facets of the FFMQ (*describing*, *acting with awareness*, *non-judging* and *non-reactivity*).

For alexithymia, all participants completed the 20-item Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994). It consists of three subscales: (1) Difficulty Describing Feelings (5 items, e.g., "It is difficult for me to reveal my innermost feelings, even to close friends."), (2) Difficulty Identifying Feeling (7 items, e.g., "When I am upset, I don't know if I am sad, frightened, or angry."), and (3) Externally-Oriented Thinking (8 items, e.g., "I prefer talking to people about their daily activities rather than their feelings."). Each item is rated on a 5-point Likert scale ('strongly disagree' to 'strongly agree'; scored 1 to 5), and 5 out of 20 items are inversely scored. A total score of 60 or above indicates a presence of alexithymia, and 52 or below indicates a definite absence of alexithymia (Parker et al., 1993). The TAS-20 is the most often used instrument for assessing alexithymia and reported to have acceptable to adequate psychometric properties across countries and cultures though internal consistency for Externally-Oriented Thinking subscale has been found to be low (e.g., Cronbach's alpha of 0.45) in some studies (review, Kooiman et al., 2002). Cronbach's alpha for the current sample ranged from 0.475 (Externally-oriented Thinking) to 0.869 (Difficulty Identifying Feelings).

Both questionnaires were completed in a quiet laboratory in the presence of a researcher.

2.3. Startle experiment: paradigm, procedure and data scoring

During the experiment, participants received 20 acoustic stimuli in total, of which 10 consisted of a 50-ms presentation of 90-dB (A) white noise and 10 consisted of a 50-ms presentation of 100-dB (A) white noise, both over 70-dB (A) continuous background noise. After one 90-dB and one 100-dB stimulus presentation, the 90-dB and 100-dB stimuli were ordered pseudo-randomly in three blocks (with each block containing three stimuli at each intensity), avoiding repetition of any particular intensity in a row. Inter-trial intervals were, on average, 20 s (range 15–25 s). The experiment began with a 2-min acclimatization period consisting of 70-dB (A) continuous white noise which was used as background noise throughout the experiment. Acoustic stimuli were presented to study participants binaurally through headphones. The experiment lasted approximately 9 min.

A commercially available computerized human startle response monitoring system (SR-Lab, San Diego, California) was used to generate and deliver the acoustic stimuli (through headphones), and record and score the EMG activity for 1000 ms (sample interval 1 ms) from the onset of the acoustic stimulus. The eye blink component of the startle response was indexed by recording EMG activity of the orbicularis oculi muscle directly beneath the right eye by positioning two miniature silver/silver chloride electrodes filled with Dracard electrolyte paste (SLE, Croydon, UK). The ground electrode was attached behind the right ear on the mastoid. The amplification gain control for EMG signal was kept constant for all participants. Recorded EMG activity was band-pass filtered, as recommended by the SR-Lab. Analogue bandpass filtering occurred before digitising. The high-pass and low-pass cut-off frequencies were at 50 Hz and 1000 Hz, respectively. EMG data were scored off-line, blind to self-report data, using the semi-automatic analytic programme of this system for response amplitude and baseline EMG (the average of the minimum and maximum values recorded during the first 18 ms for each stimulus). Prior to scoring of eye blinks, EMG data were reviewed offline on a trial-to-trial basis for each participant to exclude unusable/noisy trials, and then scored using the analytic programme of this system for response amplitude [in arbitrary Anolouge-to-Digit (A/D) units; 1 unit = 2.62 μV]. The scoring programme contained a rolling average routine (10 samples included in each average) which smoothed the rectified EMG response. Response onset was defined by a shift of 10 A/D units from the baseline value occurring within 20–100 ms from the onset of startle stimulus. The latency to response peak was defined as the latency to the point of maximal amplitude that occurred within 20–120 ms from the onset of startle stimuli. Responses were rejected if there was no visible blink response with the peak occurring within 120-ms of probe presentation. Participant's data were excluded from the dataset if >70 % trials were rejected; the maximum number of rejected trials for low or high intensity probes for the participants included in the final analysis was 5 %. Scoring criteria were identical to those reported in Sedgwick et al. (2018).

EMG recordings were taken with participants sitting comfortably in a chair in a moderately-lit psychophysiology laboratory. Participants were told before starting the experiment that they were going to hear a number of auditory clicks through headphones that they would wear over about 10 min but no action was required from them and that they should stay relaxed but keep their eyes open during this period.

2.4. Statistical analysis

The amplitude and habituation of the startle response over 90-dB and 100-dB intensity probes were the main parameters for hypothesis testing. In all analyses, data on the first two probes (one 90-dB probe, one 100-dB probe) were excluded in order to avoid exaggerated initial startle reactivity. The startle habituation was quantified as a slope across 9 trials of each intensity (over three blocks), i.e., a habituation slope for the 90-dB probes and a habituation slope for the 100-dB probes. The habituation slopes were calculated using the formula:

$$Y = a + bX$$

where X corresponds to the log-transformed startle stimulus number (trial number), Y corresponds to the square root of the response amplitude for that stimulus, a is an intercept corresponding to the level of initial reactivity (i.e., the response amplitude to the first startle stimulus), and b is the slope corresponding to the individual rate of habituation. Square-root transformed absolute amplitudes (Y of the above regression equation) that are used to calculate the slopes reduce variability, skewness, and heteroscedasticity associated with extremely large physiological responses occurring in some individuals, so calculating the slopes using square root of absolute amplitudes not only addresses the issue of standardization but also improves the data in meeting the assumptions of parametric tests when investigating the relationships of habituation with dispositional mindfulness and alexithymia measures using correlations, and when comparing the habituation slopes for low and high intensity probes. The slopes were calculated using subject-level regressions (i.e., regression performed on each individual's amplitude data separately) for all 90-dB probes (i.e., an overall habituation to 90-dB probes) and all 100-dB probes (i.e., an overall habituation to 100-dB probes). Negative slope values indicate *decreased* responding over time, with larger negative values indicating *faster* and *steeper* habituation. The approach of quantifying startle habituation using slopes has been employed in previous studies (Orr et al., 1997; Shalev et al., 1992; Antonova et al., 2015).

Response amplitude data were analysed using a 2 (Probe Intensity; 90-dB and 100-dB over 70-dB background) x 3 (Block; Blocks 1–3, with each block representing the mean value of valid responses to three probes within that block at each intensity) x 2 (Sex; males, females) analysis of variance (ANOVA) with Probe Intensity and Block as within-subjects factors, and Sex as the between-subjects factor, mainly to confirm the effects of probe intensity and explore any sex differences in these data. Effect sizes, where reported, are partial eta squared (ηp^2; the proportion of variance associated with a factor).

Correlational analyses (Pearson's *r*) were then conducted to examine the relationship of dispositional mindfulness (FFMQ total) with startle habituation slopes (main hypothesis) and the overall startle amplitude (mean startle amplitudes over 90-dB and 100-dB probes). Correlational analyses (Pearson's *r*) were also used to examine the expected negative association between self-reported dispositional mindfulness (FFMQ total score) and alexithymia (TAS-20 total score), and to explore possible associations between alexithymia and startle measures. Correlation coefficients found to be significant at alpha level 0.05 were re-evaluated after applying Bonferroni correction to control for family-wise Type-I error (Curtin and Schulz, 1998), i.e. at the alpha level of 0.0125. For this study, our a priori hypotheses involved 'dispositional mindfulness' and 'alexithymia' as constructs of interest rather than any particular facets or subscales measuring these constructs (i.e., no specific hypotheses were made in relation to FFMQ facets or TAS-20 subscales). The exploratory correlations between FFMQ facets and TAS-20 dimensions, as well as their associations with the startle measures, are therefore reported in Supplementary Tables 1 and 2, to guide hypothesis testing in future studies.

Since dispositional mindfulness and alexithymia were found to be inversely associated with each other, and both showed an association in a predicted direction (albeit at trend level for alexithymia) with startle habituation to 100-dB trials (see Results, Table 2), we explored the unique and common/shared variance explained by these trait measures in startle habituation slope (100-dB probes only) using the commonality analysis, an analysis method most often recommended for this purpose given the multicollinearity of the predictors (Kraha et al., 2012).

Lastly, baseline EMG (akin to skin conductance, a non-specific indicator of arousal in a novel laboratory environment) was analysed as a control measure to determine the specificity of the hypothesised associations with response amplitude (if found), following the same analysis strategy as described for startle response amplitude (ANOVAs and correlational analyses).

All analyses were performed using the Statistical Package for Social Sciences (for Windows, version 27; IBM, New York, USA). Alpha level for hypothesis testing was maintained at 0.05 unless stated otherwise.

3. Results

3.1. Sample characteristics

Descriptive statistics for the demographic characteristics of the final study sample as well as their mindfulness (FFMQ) and alexithymia (TAS) scores are presented in Table 1. Males and females did not differ significantly in age, mindfulness or alexithymia scores (all $p > 0.05$). There were 17 participants with a TAS total score of 52 or below (indicating absence of alexithymia), 5 people (3 men, 2 women) with a TAS score of 54–59 (borderline alexithymia), and 4 participants (2 men, 2 women) with a total score 60 or above (presence of alexithymia).

3.2. Amplitude of the startle response: probe intensity, block and sex effects

The main effect of Probe Intensity was significant [F (1,24) = 41.31, $p < 0.001$; Greenhouse–Geisser epsilon =1.00, corrected $p < 0.001$; $\eta p^2 = 0.633$] indicating higher startle amplitudes on 100-dB compared to 90-dB probes on all three blocks [Block 1: t (25) = 6.17, $p < 0.001$; Block 2: t (25) = 5.49, $p < 0.002$; Block 3: t (25) = 3.09, $p = 0.005$] (Fig. 1). The main effect of Block was also significant [F (2,48) = 12.61, p = 0.001; Greenhouse–Geisser epsilon =0.561, corrected $p = 0.001$; $\eta p^2 = 0.345$] indicating a significant reduction in startle amplitude from Block 1 to Block 3 of trials [linear F (1,24) = 12.64, $p = 0.002$] (Fig. 1). There was no main effect of Sex and no interaction involving Sex (all $F > 0.40$). There was, however, a marginally significant Probe Intensity x Block interaction [F (2,48) = 3.25, p = 0.047; Greenhouse-Geisser epsilon =0.923, corrected $p = 0.05$; $\eta p^2 = 0.119$]. This interaction was due to a significant amplitude reduction from Block 1 to Block 2 for both 90-dB [t (25) = 3.91, $p = 0.001$] and 100-dB probes [t (25) = 3.54, $p = 0.002$], but a significant reduction from Block 2 to Block 3 only for 100-dB probes [t (25) = 2.78, p = 0.032] and not for 90-dB probes [t (25) = 0.544, $p = 0.59$]. Confirming a difference between habituation to 100-dB and 90-dB probes further, we found a significantly steeper habituation slope for 100-dB probe trials (mean: −6.649, SEM: 1.659), compared to the slope for 90-dB probe trials (mean: −1.496, SEM: 0.395), across the entire experimental session (t (25) = 3.737, $p <$ 0.001).

The Probe Intensity × Block × Sex ANOVA for baseline EMG revealed no significant main or interaction effects (all $p > 0.10$).

Table 1
Sample characteristics.

	Men (n = 13)	Women (n = 13)	Entire sample (n = 26)	Entire sample
	Mean (SD)	Mean (SD)	Mean (SD)	Range
Age (years)	33.62 (11.06)	31.00 (11.19)	32.31 (10.99)	19–52
FFMQ[a]: observing[c]	20.31 (7.92)	26.31 (7.66)	23.31 (8.22)	8–40
FFMQ[a]: describing	27.23 (9.81)	29.54 (4.16)	28.38 (7.47)	11–40
FFMQ[a]: acting with awareness	27.62 (6.81)	28.46 (5.67)	28.04 (6.15)	18–40
FFMQ[a]: non-judging	27.46 (7.52)	24.77 (4.88)	26.12 (6.36)	11–40
FFMQ[a]: non-reactivity	24.00 (6.68)	21.38 (4.11)	22.69 (5.59)	10–34
FFMQ[a]: total[c]	126.61 (19.13)	130.46 (15.11)	128.54 (17.00)	81–160
FFMQ[a]: total without observing	106.31 (17.28)	104.15 (11.10)	105.23 (14.27)	71–129
TAS-20[b]: difficulty describing feelings	13.54 (2.96)	13.08 (4.01)	13.31 (3.46)	7–20
TAS-20[b]: difficulty identifying feelings	11.92 (6.55)	10.92 (4.91)	11.42 (5.69)	7–31
TAS-20[b]: externally oriented thinking	26.85 (5.34)	25.31 (5.76)	26.08 (5.50)	11–36
TAS-20[b]: total	52.31 (11.02)	49.31 (12.19)	50.81 (11.49)	28–77

[a] Five Facet Mindfulness Questionnaire.
[b] Toronto Alexithymia Scale – 20 Items.
[c] Observing facet included only for the sake of completeness (not found to exist in non-meditating samples, Baer et al., 2006, 2008; Williams et al., 2014).

3.3. Association between dispositional mindfulness and alexithymia

As expected based on previous literature, there was a negative correlation ($r = -0.513$, $p = 0.007$; 95 % CI: −0.7511, −0.1568) between dispositional mindfulness (FFMQ) and alexithymia (TAS-20) (for the exploratory correlations between FFMQ facets and TAS-20 subscales, see Supplementary Table 1).

3.4. Dispositional mindfulness, alexithymia and startle measures

As hypothesised, higher dispositional mindfulness scores were associated with stronger startle habituation (i.e., steeper slopes) over 100-dB probes with a medium-to-large effect size (Table 2, Fig. 2). The correlation between alexithymia and startle habituation, although in the expected direction, failed to reach statistical significance (Table 2). The results of the commonality analyses (Table 3) indicated that 10.6 % of explained variance (37.18 % of total explained variance) in startle habituation to 100-dB probes was common to both alexithymia and mindfulness, 17.3 % of explained variance was unique to mindfulness (61.01 % of the total explained variance), while alexithymia uniquely contributed only 0.5 % of the variance (1.82 % of the total explained variance).

The correlations between alexithymia and startle amplitudes on 90-dB and 100-dB probe trials were in the expected direction (i.e., negative) with a small-to-medium effect size but not statistically significant (Table 2). No correlation was found between dispositional mindfulness and mean startle amplitude (over the entire session) or startle habituation to 90-dB probes. Lastly, no significant associations were found (none expected) between baseline EMG and mindfulness (FFMQ) or alexithymia (TAS-20) scores (see Supplementary Table 2), confirming specificity of the hypothesised and observed relationships of mindfulness and alexithymia with startle habituation and reactivity measures.

4. Discussion

The findings of this study confirmed previously reported negative association between dispositional mindfulness and alexithymia and, for the first time to our knowledge, showed a positive association between startle response habituation and dispositional mindfulness (i.e., more habituation in individuals with a high level of naturally-occurring mindfulness) with a medium-to-large effect size. Notably, there was a significant unique contribution of dispositional mindfulness to startle habituation, with alexithymia explaining very little additional variance

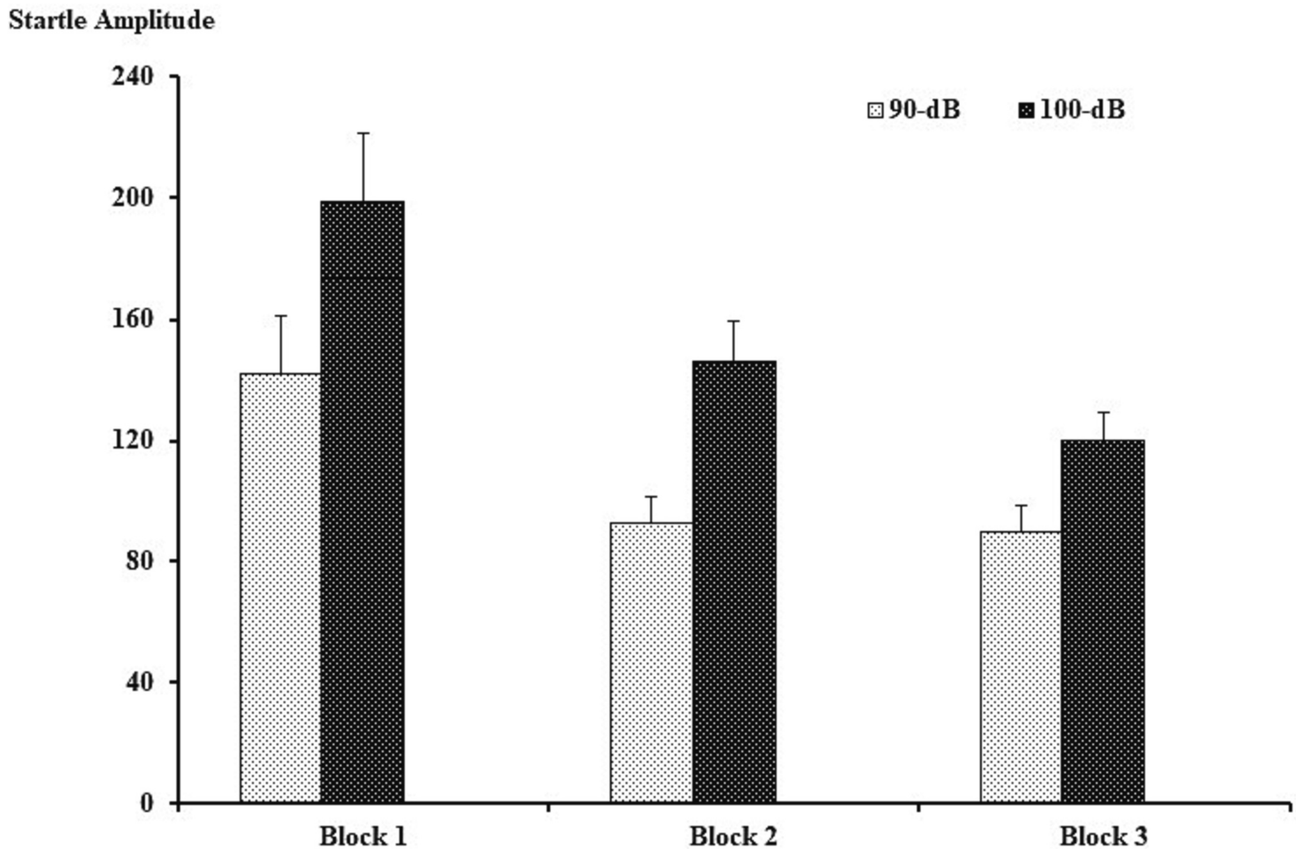

Fig. 1. Mean startle amplitudes in Analouge-to-Digit (A/D) units (1 unit = 2.62 μV) for three blocks of 90-dB and 100-dB acoustic probes. Errors bars represent +1 SEM.

Table 2
Relationship of dispositional mindfulness and alexithymia with startle measures.

	Dispositional mindfulness (FFMQ[a] total score without observing[c])		Alexithymia (TAS-20[b] total score)	
	r (uncorrected *p*) [95 % confidence interval]	*r* (uncorrected *p*) [95 % confidence interval]	*r* (uncorrected *p*) [95 % confidence interval]	*r* (uncorrected *p*) [95 % confidence interval]
	90-dB probes	100-dB probes	90-dB probes	100-dB probes
Mean startle amplitude	0.198 (0.332) [−0.205, 0.544]	0.021 (0.920) [−0.369, 0.405]	−0.358 (0.073) [−0.655, 0.034]	−0.208 (0.307) [−0.551, 0.195]
Startle habituation slope	−0.217 (0.287) [−0.557, 0.186]	−0.528 (0.006)* [−0.760, −0.177]	0.205 (0.316) [−0.199, 0.548]	0.333 (0.097) [−0.063, 0.638]

[a] Five Facet Mindfulness Questionnaire.
[b] Toronto Alexithymia Scale – 20 Items.
[c] Observing facet not found to exist in non-meditating samples (Baer et al., 2006, 2008; Williams et al., 2014).
* This correlation survived Bonferroni correction to control for family-wise Type-I error (i.e. $p \leq 0.0125$ when uncorrected p divided by 4) with four sets of dispositional mindfulness-startle measure correlations forming a family of hypotheses.

in startle habituation after accounting for the effect of dispositional mindfulness. The correlations between alexithymia and startle amplitude on high or low intensity probes were not significant, although these were present in the expected direction with small-to-medium effect sizes (i.e., higher alexithymia and lower startle amplitude). In line with previous literature (e.g., Blumenthal and Berg, 1986) and confirming our task manipulations, we observed higher startle amplitude and stronger startle response habituation on 100-dB probes, relative to 90-dB probe trials. Interestingly, associations of startle habituation with mindfulness (significant) and alexithymia (trend) were also present only for 100-dB probe trials.

Our finding of relatively stronger habituation in individuals with higher dispositional mindfulness is consistent with our hypothesis and suggests an overlap of sensory information processing styles between meditation-naïve individuals who are naturally mindful and individuals who consistently engage in mild-to-moderate mindfulness practice. In our previous study (Antonova et al., 2015), we observed more startle habituation in mild-to-moderate mindfulness practitioners but less startle habituation in long-term intense mindfulness practitioners, relative to meditation-naïve controls. The current finding, taken together with these earlier findings, suggest that, while intense long-term mindfulness practice may result in a stable state of receptive and non-preferential awareness leading to a state of ‘open presence’ and less startle habituation, a dispositional tendency to attend and be aware of inner and outer experiences without judgment and reaction may be more akin to the state of awareness or consciousness experienced by mild-to-moderate mindfulness practitioners. Alternatively, it is also possible that the only people who continue with mindfulness training

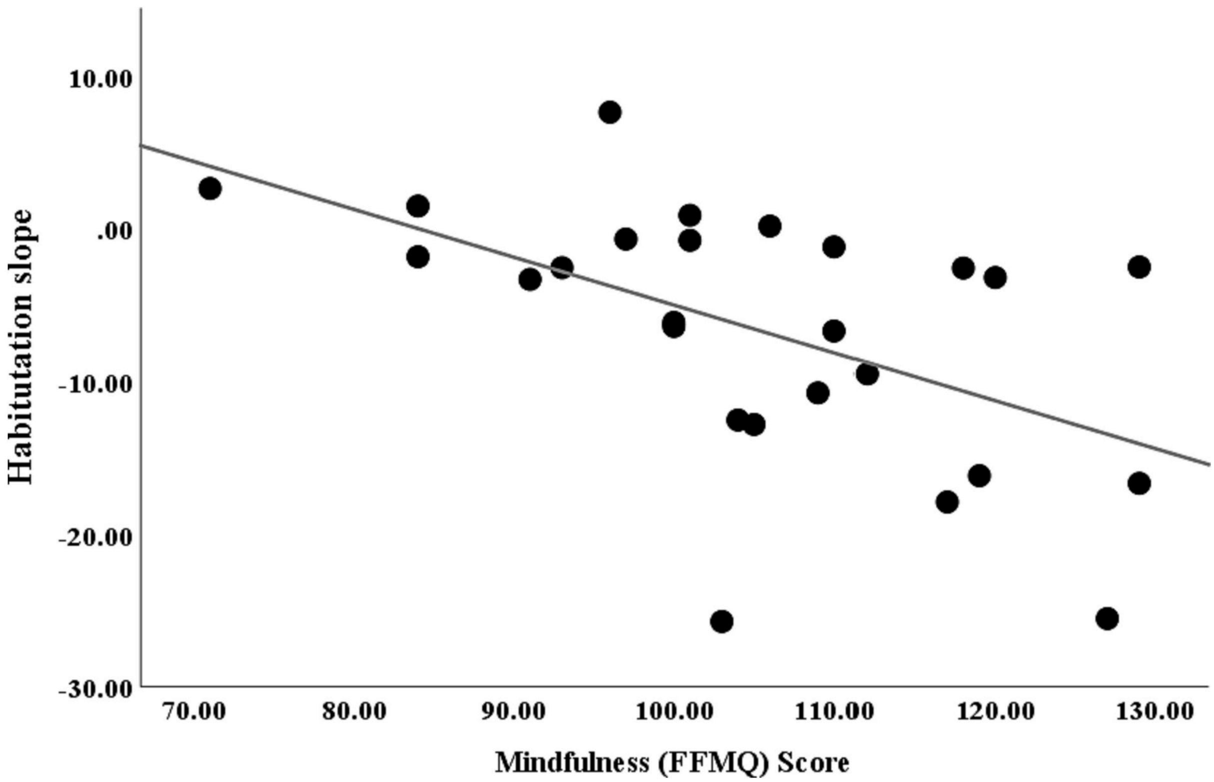

Fig. 2. Relationship between mindfulness (FFMQ Total Score without Observing) and startle habituation slope (with large negative values indicating faster and steeper habituation) over 100-dB probes.

Table 3
Results of commonality analysis showing unique and common variance explained by dispositional mindfulness and alexithymia in startle habituation for 100-dB probe trials.

	Coefficient	% total
Unique to alexithymia (TAS-20[b] total)	0.005	01.82
Unique to mindfulness (FFMQ[a] total without observing)	0.173	61.01
Common to alexithymia and mindfulness	0.106	37.18
Total	0.284	100

[a] Five Facet Mindfulness Questionnaire.
[b] Toronto Alexithymia Scale – 20 Items.

long enough to become 'mild-to-moderate practitioners' are those who already have the dispositional tendency. If so, self-report measures of dispositional mindfulness, as well as the rate of startle habituation, might provide useful predictors of training success in future studies. Extraversion, a trait reported to be positively associated with practicing mindfulness (van den Hurk et al., 2011), too has been found to be associated with faster startle habituation in some (LaRowe et al., 2006) but not all studies (Blanch et al., 2014), with this discrepancy possibly explained by marked between-study differences in stimulus and task parameters (e.g. probe intensity, number of trials, inter-trial interval) as well as habituation indices (O'Gorman, 1977). Even in the current study, a positive mindfulness-startle habituation association was present only for the 100-dB intensity probes, and not for the 90-dB probes. Further studies are needed to fully delineate the impact of dispositional or cultivated trait mindfulness and state mindfulness on habituation within different response systems which may be modulated by different, or only partially overlapping, processes and brain mechanisms (O'Gorman, 1977).

The tentatively hypothesised negative association between alexithymia and startle habituation was present only at a trend level. The commonality analysis showed that there was a sizable amount of variance (10.6 %) that was common to both mindfulness and alexithymia, a sizable unique contribution of dispositional mindfulness (17.3 %), and only a small and non-significant unique contribution of alexithymia (0.5 %) to this association. One potential explanation for the pattern of associations observed across alexithymia and mindfulness may be in terms of known links between mindfulness and (good) interoception (Gibson, 2019) and between alexithymia and (poor) interoception (emotion-specific but also non-affective) (Brewer et al., 2016; Edwards and Lowe, 2021; Trevisan et al., 2019).

A meta-analysis (Norman et al., 2019) revealed that mindfulness-based interventions that increase awareness of the present-moment experience, including awareness of bodily sensations, are effective in reducing alexithymia. Mindfulness has also been reported to influence the structural and functional properties of the insula (reviews, Gibson, 2019, Pernet et al., 2021), a key brain area involved in interoceptive awareness (Craig, 2009; Singer et al., 2009) and implicated in alexithymia (e.g., Hogeveen et al., 2016). Furthermore, an increase in right insula thickness has been found to correlate with a decrease in alexithymia following mindfulness-based training in meditation-naïve individuals (Santarnecchi et al., 2014). Interestingly, the visceral afferent signals which contribute to interoceptive awareness (Dworkin, 2007) have also been found to modulate eyeblink startle response (e.g., Münch et al., 2019), lending further support to our proposed explanation of observed startle habituation-mindfulness association. Future studies investigating the mechanisms underlying the associations of mindfulness and/or alexithymia with startle habituation and reactivity (amplitude) should utilise the objective measure(s) of interoceptive awareness.

Our observations also point towards a possible negative association between alexithymia and startle amplitude with a small-to-medium effect size that may be worthy of future research involving sufficiently large sample sizes, given the known association of alexithymia with depression (Li et al., 2015) and hypertension (Casagrande et al., 2019; Jula et al., 1999), both of which have been linked with hypo-startling (e.g. Kaviani et al., 2004; Shukla et al., 2020). There may well be a common mechanism linking these conditions characterised by affective difficulties and reduced amplitude of the (defensive) startle reflex response, possibly mediated by the amygdala (Davis et al., 1999).

The main limitations of the study include the sample size allowing for 80 % power to detect medium-to-large correlations (r coefficients of 0.467 or above), but insufficient for reliably detecting small-or medium-sized correlations. Based on our power analysis using G*power3 with the effect sizes observed in this study (Faul et al., 2007), 52 and 141 people are needed to detect the negative association between alexithymia and startle amplitude to 90-dB (observed $r = -0.340$) and 100-dB probes (observed $r = -0.208$), respectively, with 80 % power to be significant at $p < 0.05$ level. Furthermore, the current experiment had only 10 trials per probe intensity (9 analysed), with the startle habituation slopes calculated across all trials over three blocks at each of the two intensities. Future studies should examine individual differences in habituation over a longer session with more trials in each block, allowing to estimate habituation slopes for each block separately to better quantify habituation over the course of the experiment, considering the potential startle response recovery between two consecutive blocks. It might also be of interest to quantify startle habituation with and without discarding the initial probes; these are usually discarded as the startle blink to the initial probe may be exaggerated in size before a more gradual habituation occurs. This initial reactivity to the first trial might hold relevant information for the studies of individual differences in relation to the main constructs of the study. Overall, given the limitations, our findings encourage further research with sufficiently large sample sizes and extended (number of trials per block) habituation paradigms to further test our observations and to examine interoceptive awareness as a potential psychological mechanism underlying faster and stronger habituation in people with high dispositional mindfulness and/or low alexithymia, along with associated neural mechanisms. Our findings also highlight potential utility of startle-based objective markers to examine the effectiveness of mindfulness-based interventions in reducing alexithymia and depression.

5. Conclusions

The findings of this study confirm a significant negative association between dispositional mindfulness and alexithymia as reported in previous studies (Teixeira and Pereira, 2015), and indicate similar or overlapping sensory information processing styles, at least as indexed by habituation of the startle response, in people who are naturally mindful to those reported previously (Antonova et al., 2015) in long-term mindfulness practitioners engaging in mild-to-moderate meditation practices. In addition, lower startle amplitude in association with alexithymia, if found in future studies with sufficiently large sample sizes, may suggest an overlapping profile of people with alexithymia, elevated blood pressure (Shukla et al., 2020) or depression (Allen et al., 1999; Dichter and Tomarken, 2008; Kaviani et al., 2004).

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijpsycho.2022.12.002.

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