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Does stress exacerbate impairments in attentional control in trait impulsive individuals?

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ABSTRACT

Evidence suggests that impulsivity is characterised by impairments in attentional control, which is required to regulate stress levels. Given that elevated stress levels can impair attentional control as well, it was predicted that trait impulsivity and stress would interact. Whereby high stress levels would amplify the impairments to attentional control in high impulsive individuals, who are less able to regulate this stress. To test this, the levels of attentional capture and unintentional mind-wandering were assessed at different levels of stress and impulsivity. Unexpectedly, however, across 3 Studies (N = 108; 290; 157) there was no evidence supporting this amplification hypothesis. The findings instead revealed that stress and impulsivity were related to attenuated processing of target-matching external distractors, consistent with inattention (Study 1 & 3); and though they did significantly interact in Study 1, this was more reflective of the trait-impulsivity obscuring the additional influence of high stress on attention. Further, stress and impulsivity also independently predicted elevated unintentional mind-wandering without interacting, both when self-reported (Study 2) and when assessed during the attentional capture task (Study 3). The unexpected lack of interaction across multiple measures is discussed, and implications of the independent effects for existing models considered.

1. Introduction

Trait impulsivity is a multi-faceted personality trait characterised by a disposition to unplanned rash decision making, disinhibited responding, and the prioritisation of short-term rewards at the cost of long-term effortful goals (Evenden, 1999; Whiteside & Lynam, 2001). Evidence suggests that it is a heritable trait distributed across the population as a continuum (Bezdjian et al., 2011). At moderate levels it can be expressed as adaptive sensation seeking and extraversion (Degnan et al., 2011), however, at higher levels it is linked to poorer health outcomes and quality of life (Chamberlain & Grant, 2019; Mobbs et al., 2010). One route by which this may occur is through poorer attentional control.

Though many investigations exploring impulsivity often focus on decision making and response disinhibition elements, the ability to control sustained attention is also a key element of impulsivity in many models (De Wit, 2009; Patton et al., 1995; Sharma et al., 2014). For instance, deficits in attentional control often occur in conditions also characterised by high levels of impulsivity, such as ADHD (Seli et al., 2015); and it has been found that, alongside decision making, the ability to control sustained attention is a strong predictor of impulsive reward seeking behaviours (i.e., alcohol and illicit drug use, and gambling; Verdejo-Garcia et al., 2021). Impairments in the ability to control attention therefore appear to be a key mechanism of impulsivity whereby individuals become inattentive of long-term adaptive goals, and become distracted by competing short-term maladaptive rewards.

As well as impulsive individuals struggling to regulate maladaptive behaviour, trait impulsivity is also linked to more difficulties with regulating negative emotions (Schreiber et al., 2012); and is linked to more internalising mental health conditions such as anxiety and depression (Fields et al., 2021; Moustafa et al., 2017). A key candidate mechanism for this emotional dysregulation may again be attentional control, as regulation requires the shifting of attention away from negative thoughts, and focus on adaptive regulation strategies (e.g., reappraisal; Eysenck et al., 2007; O'Bryan et al., 2017). Thus, trait impulsivity is strongly linked to experiencing more frequent and prolonged bouts of negative emotion, including stress, partly due to impairments in attentional control.

This may be especially problematic, as it has been found that higher levels of stress can induce a range of impulsive behaviours (e.g., rash decision making and response disinhibition; Dierolf et al., 2017; Fields et al., 2014; Herman et al., 2018; Whiteside & Lynam, 2001), including increased distraction and lapses in control over sustained attention

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(Shields et al., 2016). Given that 1) trait-impulsive individuals are less able to regulate negative emotions, and experience more frequent elevated stress; and 2) elevated stress itself can induce further impulsivity and impair attentional control, it is possible that stress acts to amplify existing impairments in attentional control in trait-impulsive individuals.

Within earlier work, emotion-induced impulsivity (aka negative urgency) has been suggested to be independent of other non-affective impulsive traits, with reported emotion-induced impulsivity loading on different factors to non-affective traits such as non-planning and perseverance (Smith et al., 2007). The independence of trait impulsivity and emotion-induced impulsivity is, however, rarely directly tested. Instead, the focus has been on the interaction between state-level stress/arousal and trait-level emotion-induced impulsivity in isolation from other facets of impulsivity (e.g., Pearlstein et al., 2022).

The current investigation therefore sought to test the general hypothesis that individuals who report higher trait impulsivity will experience greater impairments in attentional control, and that this will be even greater in impulsive individuals who also report recently experiencing higher levels of stress. To assess multiple aspects of attention, both attention to irrelevant external visual distractors as well as task-unrelated internal thoughts were measured across three studies.

2. Study 1

The measure of external attentional capture used was the Rapid Serial Visual Presentation (RSVP) task (Raymond et al., 1992). In this task, multiple letters are briefly presented in rapid succession, if a stimulus captures attention earlier in the sequence then participants are more likely to miss a target which appears close in time to the distractor (e.g., Lag of 2 intervening stimuli between distractor and target, versus a Lag of 6 intervening stimuli), in a phenomenon known as the ‘attentional blink’.

The current task used was a contingent capture RSVP, where participant must identify a letter which appears in a specific colour in a sequence of irrelevant coloured letters. Peripheral distractors above and below the stream, which can match or mismatch the target colour, are presented prior to the target to assess their ability to disrupt target detection even when spatially irrelevant (Folk et al., 2002). In this paradigm, attentional capture caused by target-matching colours is driven more by feature relevance, whilst distraction by target-mismatching colours is more reflective of purely salience-driven distraction.

Previous evidence using the RSVP task with multiple targets has found that highly impulsive individuals exhibit stronger attentional capture/blink due to them over-committing their attention to earlier task-relevant stimuli, resulting in them missing a second target (Baskin-Sommers et al., 2012; Li et al., 2005). On the other hand, other paradigms have found entirely task-irrelevant distractors with no target features capture attention more for impulsive individuals as well (Forster & Lavie, 2016). It is, therefore, expected that impulsive individuals will be distracted more by both target-matching and mismatching coloured distractors, and that this will be amplified by higher levels of stress.

2.1. Methods

2.1.1. Participants

An initial sample of 121 volunteers completed the study online as part of an undergraduate workshop which ran in January 2021. The participants completed the experiment on their personal computers at home.

Nine participants were initially excluded for not completing the full experimental session, for having a computer without a refresh rate of 60 Hz, or for accuracy below 30% in the easiest no distractor condition. A further four participants were excluded due to their mean attentional capture index (i.e., Lag2 versus Lag6 accuracy) exceeding 3SD from the mean. Participants were also excluded if the total frequency that they gave an identical response to sequential opposite coded items in the Barrett Impulsiveness Scale (BIS-11; Patton et al., 1995, see below) was greater than 2SD from the mean (i.e., adapted long-string analysis).

After exclusions, the final sample consisted of 108 participants, the mean age was 20.14 (SD = 3.47, range = 18–46). Ninety-four participants identified as female, 12 male, and 2 as a different gender. The sample size was based on the maximum number of participants who could be recruited from the available undergraduate online workshop attendees.

2.1.2. Ethics

Ethical approval for all studies were awarded by the local ethics committee and was run in accordance with the Declaration of Helsinki. The relevant ethics codes for all studies are PSYC_20_369 (28/10/2020) and PSYC_20_372 (14/10/2020).

2.2. Stimuli and materials

2.2.1. RSVP task

The RSVP task was adapted from Folk et al. (2002), in which participants identified a single letter which appeared in a specific colour (Fig. 1). In Study 1 the target colour was randomly allocated to participants, with 46% searching for green targets, and the other 54% searching for orange targets.

The target letter appeared equally at positions 8, 10, 12, and 14 in a 15 letter RSVP stream for all conditions. All non-target letters and colours were randomly selected each trial, with non-target letter colours consisting of turquoise, white, navy blue, gold, light blue, red, and brown (each appearing twice per trial). The non-target letters presented were: A, B, E, F, H, J, K, M, P, Q, R, S, U, and Y. The letters which appeared as targets were: C, D, N, O, U, V, X, and Z. Each target letter appeared an equal number of times within each condition. All letters were presented in size 32 Arial Bold font.

Each letter appeared for 67 ms, followed by a 50 ms blank inter-stimulus interval, after which participants were prompted with a ‘?’ symbol to report the identity of the target letter. A 500 ms feedback screen with the text “CORRECT!” was then presented after correct responses, whilst no feedback was given on incorrect trials.

The distractor frame in the RSVP included two additional ‘#’ symbols above and below the central position. One of the distractor symbols appeared in either a target-matching/mismatching colour and the other in grey, the coloured distractor location was counterbalanced across all conditions. Stimulus locations were determined by a calibration procedure, whereby participants adjusted the length of a 480-pixel line to match the size of a bank card. This adjustment was then applied to the stimuli, resulting in the distractor appearing at 2 cm eccentricity from the centre of the screen. The distractor symbol appeared in size 56 Arial Bold font.

There were 3 blocks of 96 trials with a self-determined break period in between. Each block consisted of 32 trials with no distractor, 32 trials in which the peripheral distractor matched the colour of the target, and 32 trials in which the distractor mismatched the colour of the target. On distractor present trials, half the time it was presented two letters prior to the target letter (Lag2), on the other half it appeared 6 letters prior to the target (Lag6). Target position, Distractor type, Distractor position, and Lag were all counterbalanced within each block.

The task was preceded by a practice phase consisting of 12 slower example trials where letters appeared for 167 ms with an ISI of 67 ms, followed by a 12-trial practice block at full speed. Participants had to achieve over 60% accuracy on the example block to proceed to the practice, and 30% on the practice block to proceed to the main task, otherwise the blocks re-ran (11.1% of participants repeated either the example or practice block more than once). In both example and practice blocks, no distractors were presented, target appeared equally at the

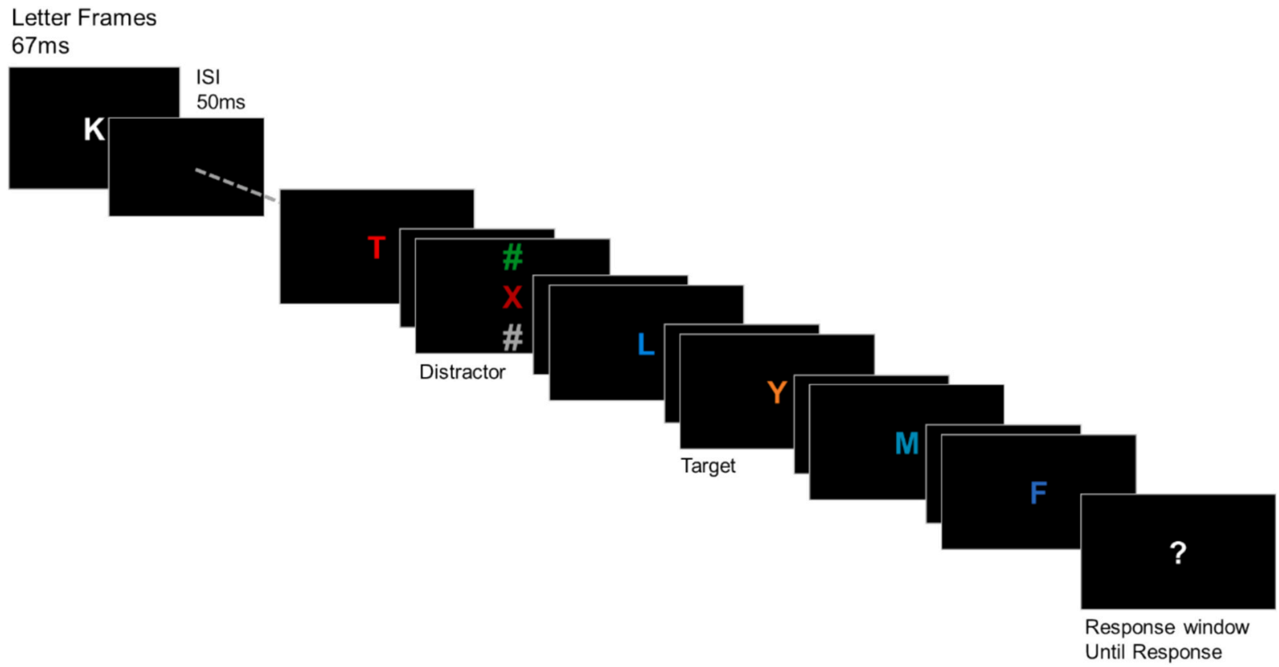

Fig. 1. Partial trial sequence depicting the target-mismatch Lag2 distractor condition. See online publication for full colour version.

4 temporal locations, and the target letter was randomly selected.

2.2.2. *Barrett impulsiveness scale (BIS-11; Patton et al., 1995)*

The BIS-11 measures impulsive behaviours across a 30-item scale, designed to measure different aspects of impulsivity (e.g., "I do things without thinking"). Responses were along a 4-point scale ranging from "Rarely/never" to "Almost always/always".

2.2.3. *Perceived psychological stress scale (PSS; Cohen et al., 1983)*

The PSS is a 14-item scale designed to measure perceived stress as a single factor, and includes items such as "In the last month, how often have you felt that you were on top of things?". Responses are along a 4-point scale ranging from "Never" to "Very often". Participants were instructed to respond based on experiences in the past month.

2.2.4. *UPPS-P scale short form (Cyders et al., 2014)*

The UPPS-P scale short form is a 20-item scale, which is designed to measure the different facets of impulsivity with a specific focus on negative and positive emotions (e.g., "When I am upset I often act without thinking"). Responses are made along a 5-point scale, ranging from "Agree strongly" to "Disagree strongly".

2.3. *Procedure*

Participants accessed the study through an online Inquisit link. After providing informed consent, participants completed the screen calibration procedure. Prior to the task, participants were instructed to wear glasses or contact lenses if required and to sit approximately 60 cm from the screen. Participants then completed the RSVP task, followed by the PSS, BIS-11, and UPPS-P in a random order. Finally, participants completed demographic information.

2.4. *Results*

All data and analyses scripts across studies are available via the OSF: https://osf.io/quzpd.

Internal reliability for self-report measures was analysed with Cronbach's alpha, this revealed acceptable to excellent reliability across most self-report measures (α > 0.70; see Table 1). The negative urgency subscale of the UPPS-P scale however showed poor reliability (α = 0.67).

Table 1
Descriptive statistics and Cronbach's alpha statistics for all self-report measures in Study 1. Descriptives reflect average score (rather than sum), to gauge position on response scale. BIS (response range: 1–4), PSS (response range: 1–4), UPPS-P (response range: 0–4).

	Mean	SD	Cronbach's α
BIS-11 total	2.17	0.33	0.82
PSS	2.23	0.28	0.88
UPPS-P: Negative Urgency	2.42	0.69	0.67
UPPS-P	2.16	0.35	0.77

Assessing the skewness and kurtosis scores computed from the skewness/kurtosis statistic and their standard error revealed that the target-matching capture index (i.e., Lag6 minus Lag2 difference) was positively skewed ($Z > \pm 1.96$). To account for this violation of normality, 95% confidence intervals (1000 iterations) were bootstrapped for all analyses (Kelley, 2005), details of bootstrapping procedures are given for each specific analysis. Effects with 95% confidence intervals which do not encompass zero would be equivalent to significance of $p < .05$.

2.4.1. *Impulsivity × stress interaction model in attentional capture*

To analyse the proposed interaction between impulsivity and stress in predicting attentional capture in the RSVP task, a Generalised Linear Mixed Model (GLMM) analysis was conducted with the trial-level accuracy as outcome variable, using the *lme4* R package (Bates et al., 2015). The GLMM analysis was used rather than ANOVA and regression due to its compatibility for complex designs with multiple categorical and individual differences continuous measures, required for the current investigation (Kliegl et al., 2011). Bootstrapped intervals for the overall GLMM analyses were computed using the *confint* R function from the R *stats* package.

A preliminary analysis with only Lag (Lag2 versus Lag6) entered the GLMM as a fixed effects predictor (and participant unique identifier as random effects predictor), revealed a significant difference in target identification probability between Lag2 and Lag6 for target-matching distractors (Table 2). This same analysis for target-mismatching

Table 2
Contrasts between Lag2 and Lag6 distractor conditions for target-match and mismatch distractors in Study 1, as well as split-half reliability analyses of these contrasts. CI = confidence interval; LB = lower bound; UB = upper bound. Standard errors in parantheses.

		Estimated Detection Probability			Attentional Capture Index			Split-half reliability	
	Distractor condition	No distractor	Lag2	Lag6	χ^2	*p*-value	Cohen's d	r_{sb}	95% CI [LB, UB]
Study 1	No distractor	0.79 (0.02)	–	–	–	–	–	–	–
	Target-matching	–	0.66 (0.02)	0.76 (0.02)	116	< 0.001	−0.27	0.58	[0.46, 0.69]
	Target-mismatching	–	0.79 (0.02)	0.80 (0.02)	1.6	0.206	−0.03	0.29	[0.07, 0.48]

distractors revealed no significant difference. To assess the reliability of the capture effects, a split-half correlation analysis was conducted on the contrast between Lag2 and Lag6 using a permutation approach (1000 iterations) in the *splithalf* R package (Parsons, 2021). For target-matching distractors, the split-half Spearman-Brown (r_{sb}) correlation between the randomly sampled Lag contrasts was moderate to large, but was small and non-significant for target-mismatching distractors (Table 2).

To assess the hypothesised interaction between stress and impulsivity, these variables were standardised and then entered into the GLMM as fixed effects, alongside the dichotomous lag variable. The key three-way interaction (along with all two-way interactions and main effects) were also modelled as fixed effects predictors. Unique participant identifier was modelled as a random effects factor.

This analysis was repeated separately for trials when distractor was target-matching and when the distractor was target-mismatching. For the first GLMM analysis of target-matching distractors neither impulsivity, $\beta = 0.10$, 95% $CI_{bootstrapped}$ [−0.07, 0.26], stress, $\beta = 0.12$, 95% $CI_{bootstrapped}$ [−0.05, 0.29], or their interaction, $\beta = -0.08$, 95% $CI_{bootstrapped}$ [−0.25, 0.09], significantly predicted variation in general target identification probability. The interaction between impulsivity and distractor-target lag was significant, $\beta = -0.09$, 95% $CI_{bootstrapped}$ [−0.19, −0.003], as was the relationship between stress score and distractor-target lag, $\beta = -0.12$, 95% $CI_{bootstrapped}$ [−0.21, −0.03]. Additionally, the three-way interaction was also significant, $\beta = 0.16$, 95% $CI_{bootstrapped}$ [0.07, 0.25].

To understand the interaction, a simple slopes analysis was conducted (Aiken & West, 1991), which assess the relationship between the differences in target detection probability at Lag2 and Lag6, at all combinations of Low (-1SD) and High (+1SD) levels of stress and impulsivity. Estimated marginal mean probability of target identification for each contrast at each level was computed using the *emmeans* R function (Lenth, 2021). The difference in log Odds Ratio (logOR) and Cohen's d effect size was computed for each of the Lag2 versus Lag6 contrasts. For every contrast at different levels of impulsivity and stress, 95% confidence intervals were bootstrapped (1000 iterations) around the logOR difference estimate using manual resampling due to the complexity of the design.

This analysis revealed an unexpected effect: The significant three-way interaction did not reflect an amplification of attentional capture in high impulsivity individuals at higher levels of stress (Fig. 2). Instead, the largest difference between Lag6 and Lag2 detection probability was observed in low stress low impulsive individuals, $M_{Lag2} = 0.59$, SE = 0.03, $M_{Lag6} = 0.77$, SE = 0.03, logOR = −0.81, 95% $CI_{bootstrapped}$ [−1.09, −0.53], d = −0.45, highly impulsive individuals at low levels of stress actually experienced lower levels of attentional capture with the effect of lag becoming non-significant, $M_{Lag2} = 0.68$, SE = 0.04, $M_{Lag6} = 0.74$, SE = 0.04, logOR = −0.29, 95% $CI_{bootstrapped}$ [−0.57, 0.002], d = −0.16. Contrasting, the magnitude of the capture effects between low and high impulsive individuals, at low stress levels, confirmed that impulsivity significantly attenuated attentional capture, logOR = 0.51, 95% $CI_{bootstrapped}$ [0.10, 0.98], d = 0.29.

At high levels of stress, the influence of impulsivity had a negligible effect on attentional capture, with high impulsive individual showing a similar effect of Lag, $M_{Lag2} = 0.69$, SE = 0.03, $M_{Lag6} = 0.77$, SE = 0.03, logOR = −0.40, 95% $CI_{bootstrapped}$ [−0.65, −0.16], d = −0.22, as low impulsive individuals, $M_{Lag2} = 0.69$, SE = 0.04, $M_{Lag6} = 0.74$, SE = 0.04, logOR = −0.25, 95% $CI_{bootstrapped}$ [−0.55, 0.03], d = −0.14. There was no significant difference between these capture effects between low and high impulsivity, logOR = −0.14, 95% $CI_{bootstrapped}$ [−0.52, 0.23], d = −0.08, with both lag contrasts being relatively weak at high stress, and low impulsive individuals showing a non-significant effect of lag at high stress.

It therefore appears that rather than highly impulsive individuals experiencing higher levels of external distractibility, these individuals experience generally lower distraction independent of stress.

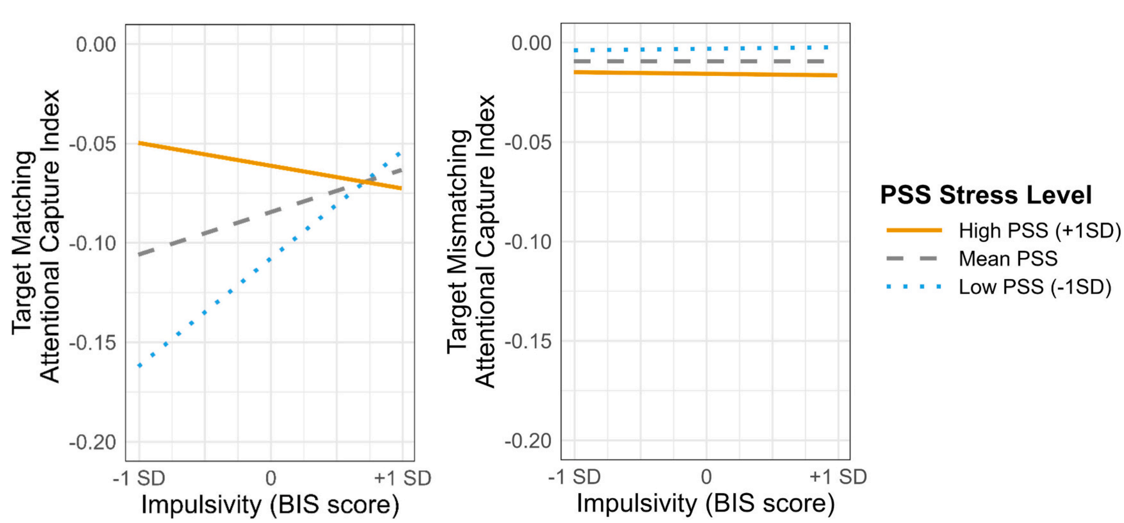

Fig. 2. Illustration of the simple slopes analysis of the average attentional capture index (difference between Lag2 and Lag6 accuracy) for target-matching and mismatching distractors at low and high perceived stress scale (PSS) and impulsivity scores, for Study 1.

Additionally, stress also unexpectedly attenuated attentional capture, but only in low impulsive individuals, bringing them to the same level of attentional capture as high impulsive individuals.

Repeating the GLMM analysis with the target-mismatch accuracy revealed no significant effect of stress or impulsivity on target identification probability, $\beta < 0.05$, $\chi^2(1) < 0.45$, $p > .503$, and showed no significant interaction effect with target-distractor lag, or three-way interaction, $\beta < 0.01$, $\chi^2(1) < 0.08$, $p > .771$. All bootstrapped confidence intervals were inclusive of zero.

2.5. Discussion

Study 1 found no evidence that stress amplified distraction by target-matching or -mismatching irrelevant distractors in trait-impulsive individuals, and actually showed an opposing effect: high impulsive individuals experienced lower attentional capture by target-matching distractors, with this being more apparent at low levels of stress. Conversely, at high levels of stress all individuals experienced similarly low levels of attentional capture, regardless of impulsivity.

3. Study 2

Though it could be inferred from Study 1 that high impulsivity and stress ostensibly strengthened attentional control over external distractors, an alternative interpretation could be that it reflects lower distractor processing due to inattention towards the task. As well as failures to inhibit external distractors, both stress and impulsivity have been linked to higher trait and state levels of unintentional mind-wandering (Arabacı & Parris, 2018; Gay et al., 2011; Mattioni et al., 2023). This is especially relevant in the current context, as higher levels of mind-wandering can cause lower processing of external stimuli, including task-irrelevant distractors (Barron et al., 2011; Handy & Kam, 2015).

Therefore, to explore whether the evidence of lower attentional capture could be due to increased inattention towards the task, Study 2 assessed impulsivity and stress's relationship with self-reported mind-wandering. If previous effects were due to increased inattention rather than increased control, it would be expected that stress and impulsivity would predict higher mind-wandering, and that they would interact as in study 1, whereby the independent effect of impulsivity on mind-wandering would be stronger at lower levels of stress, but obscured at higher levels of stress. This hypothesis was pre-registered via the Open Science Framework (OSF; https://osf.io/u6jhz).

Given that attentional control is also required to ignore irrelevant spontaneous thoughts and maintain sustained attention, Study 2 also allowed the test of the original amplification hypothesis. In this instance, however, rather than elevated external distraction as the outcome variable, this hypothesis would predict that unintentional mind-wandering would be amplified by stress in high impulsive individuals.

3.1. Methods

3.1.1. Participants

An initial sample of 394 participants responded to the survey link, which was disseminated via social media or the student participant pool between October 2021 and May 2022. Participation was either in exchange for course credit or voluntary. A total of 95 participants were excluded for only partially completing the study, and a further nine were excluded for repetitive responding (as in Study 1).

The final sample consisted of 290 participants, of which 223 were female, 57 were male, 7 reported identifying as a different gender, and 3 chose not to report their gender. Due to a programming error in some surveys, age data was only collected for 257 participants. The average age from this sample was 30.88 (SD = 14.41). Study 2's methods, hypotheses, recruitment strategy, and analyses were pre-registered on the OSF (https://osf.io/jmhct), deviation from the registration are noted in the relevant sections.

The registered target sample was 182 participants, which was based on a power analysis derived from a preliminary analysis of Study 1 without full exclusion criteria applied. Within this initial analysis, impulsivity correlated with attentional capture, $r = -0.235$ ($\alpha = 0.05$, $1-\beta = 0.90$, two-tailed). The formal analysis of the Study 1, however, revealed a smaller effect size ($r = 0.20$; see Supplementary materials 2 for full correlations). The minimum sample to achieve this updated effect was 255 participants ($\alpha = 0.05$, $1-\beta = 0.90$, two-tailed). Due to time constraints, the sample size after exclusions was checked at the end of each academic term. This resulted in Study 2's sample size of 290 exceeding both the initial and updated minimum sample sizes.

3.2. Stimuli and materials

3.2.1. Depression, anxiety & stress scale (DASS-21; Lovibond & Lovibond, 1995)

The DASS-21 is a 21-item measure, measure stress, anxiety, and depression, though the 7-item stress subscale was the variable of interest (e.g., "I found it difficult to relax"). Responses were along a 4-point scale ranging from "Never" to "Almost always". Participants were instructed to respond based on experiences over the past two weeks.

3.2.2. Spontaneous and deliberate mind-wandering scales (S-MW & D-MW; Carriere et al., 2013)

Intentional/deliberate and unintentional/spontaneous mind-wandering was measured through two 4-item scales developed by Carriere et al. (2013). Intentional mind-wandering was measured with items such as 'It feels like I don't have control over when my mind wanders'; whilst intentional mind-wandering was measured with items such as 'I find mind-wandering is a good way to cope with boredom'. Responses were along a 7-point scale ranging from either 'rarely'/'not true at all' to 'a lot'/'very true'. Participants were instructed to respond based on experiences over the past two weeks.

3.3. Procedure

Participants accessed the study through a Qualtrics survey link. After the consent procedure, participants completed the DASS-21, BIS-11, and then the S-MW and D-MW scales in sequence. These were answered as part of a battery of five other self-report measures related to a separate research question about mental imagery and addiction (see Supplementary materials 1 for list of measures). Finally, participants completed demographic information.

3.4. Results

For analytic consistency, a linear model analysis using the *lm* function from the *stats* R package was used to analyse the mind-wandering data, rather than the pre-registered regression/correlation analyses. An additional deviation from the pre-registration was that DASS-21 stress score was the dependent variable rather than DASS total score.

Internal reliability analyses of all self-report measures revealed good to excellent reliability (Table 3). Assessing the skewness and kurtosis

Table 3
Descriptive statistics and Cronbach's alpha statistics for all self-report measures in Study 2. Descriptives reflect average score (rather than sum), to gauge position on response scale. BIS (response range: 1–4), DASS (response range: 0–3), S-MW and D-MW (response range: 1–7).

	Mean	SD	Cronbach's α
BIS-11 total	2.19	0.57	0.82
DASS stress	1.20	0.57	0.81
DASS total	1.04	0.53	0.92
S_MW	4.36	1.59	0.87
D_MW	4.39	1.54	0.84

scores (as in Study 1), revealed that both intentional and unintentional mind-wandering was negatively skewed, and stress positively skewed ($z > \pm 1.96$). To account for this violation of normality, significance was interpreted from bootstrapped 95% confidence intervals (1000 iterations; Kelley, 2005). These were computed using the *confint* R package for linear model analysis, and *boot* package for follow-up simple slopes analyses (Canty & Ripley, 2025).

3.4.1. *Impulsivity × stress interaction model in mind-wandering*

The linear model analysis revealed that both impulsivity, $\beta = 0.36$, $CI_{bootstrapped}$ [0.25, 0.48], $\eta p2 = 0.13$, and stress, $\beta = 0.21$, $CI_{bootstrapped}$ [0.10, 0.32], $\eta p2 = 0.05$, were significant predictors of higher unintentional mind-wandering. The interaction was, however, non-significant, $\beta = -0.07$, $CI_{bootstrapped}$ [−0.15, 0.01], $\eta p2 = 0.01$ (Fig. 3).

Analysis of intentional mind wandering revealed that impulsivity was a significant predictor of high intentional mind-wandering, $\beta = 0.19$, $CI_{bootstrapped}$ [0.07, 0.32], $\eta p2 = 0.03$. Whilst stress was not a significant predictor on its own, $\beta = 0.01$, $CI_{bootstrapped}$ [−0.11, 0.14], $\eta p2 = 0.03$, the interaction between impulsivity and stress, was significant, $\beta = -0.15$, $CI_{bootstrapped}$ [−0.24, −0.05], $\eta p2 = 0.03$.

A follow-up simple slopes analysis assessing the association between impulsivity at both low and high levels of stress revealed that the magnitude of the relationship between impulsivity and intentional mind-wandering was stronger at low levels of stress, $\beta = 0.34$, 95% $CI_{bootstrapped}$ [0.19, 0.49], $\eta p2 = 0.06$, relative to high levels of stress where the difference between low and high impulsivity was non-significant, $\beta = 0.05$, 95% $CI_{bootstrapped}$ [−0.13, 0.21], $\eta p2 < 0.01$. The contrast between these slopes was also significant, $\beta = 0.29$, 95% $CI_{bootstrapped}$ [0.11, 0.51], confirming the difference.

As in Study 1, the interaction therefore reflected stress pushing low impulsive individuals to the same level of inattention as high impulsive individuals, and the influence of stress having little effect on the already high levels of deliberate/intentional thought of high impulsive individuals.

Bayesian correlations were registered for Study 2, however, to ensure consistency of analytic framework, only the frequentist analysis was conducted to avoid conflicting interpretations (Dienes, 2024). All zero-order correlations are reported in Supplementary materials 2.

3.5. *Discussion*

The results of Study 2 further contradicted the initial hypothesis that stress would amplify impairments in attentional control in high impulsive individuals, specifically, stress and impulsivity independently predicted unintentional mind-wandering; or in the case of intentional mind-wandering, interacted due to stress elevating the level of mind-wandering in low impulsive individuals to the same level as high impulsive individuals.

Further, it raises the possibility that the attenuated attentional capture in Study 1 could be due to impulsivity and stress causing inattention to task stimuli. Whilst Study 2's findings are consistent with this interpretation, especially for intentional mind-wandering, they are based on self-reported mind-wandering over the past 2-weeks, making it difficult to generalise to inattention during the task.

4. Study 3

Study 3 aimed to further test whether the pattern observed with self-reported mind-wandering could be replicated with current state-levels of intentional and unintentional mind-wandering; and whether this mediated impulsivity and stress's negative relationship with attentional capture found in Study 1. To do this the RSVP task was replicated but with the addition of thought probes presented randomly during the task and at the end of each block. To assess the degree that task-unrelated thoughts were under voluntary control, these probes asked the degree that task-unrelated thoughts were intentional or unintentional (as in Seli et al., 2016).

Furthermore, Study 3 allowed the replication of evidence against the initial stress amplification hypothesis with both external visual attentional capture and internally focused unintentional mind-wandering in the same task. Study 3's methods, hypotheses, recruitment strategy, and analyses were pre-registered on the OSF (https://osf.io/jmhct), deviations from the registration are noted in the relevant sections.

4.1. *Methods*

4.1.1. *Participants*

An initial sample of 256 participants responded to the online study link, which was advertised to participants via social media or to the student participant pool between October 2022 and June 2024. Participation was either in exchange for course credit or voluntary. The identical exclusion criteria utilised in Study 1 were then applied with the additional exclusion of self-reported colour-blind participants. This resulted in the initial exclusion of 88 participants, followed by the further exclusion of 11 participants due to performance-based exclusions (i.e., task performance outliers, repetitive responders).

The final sample of participants was 157, of which 130 were female, 23 male, and 3 reporting a different gender. The mean age was 23.64 years, SD = 9.93.

As with Study 2, the required sample size was based on the effects

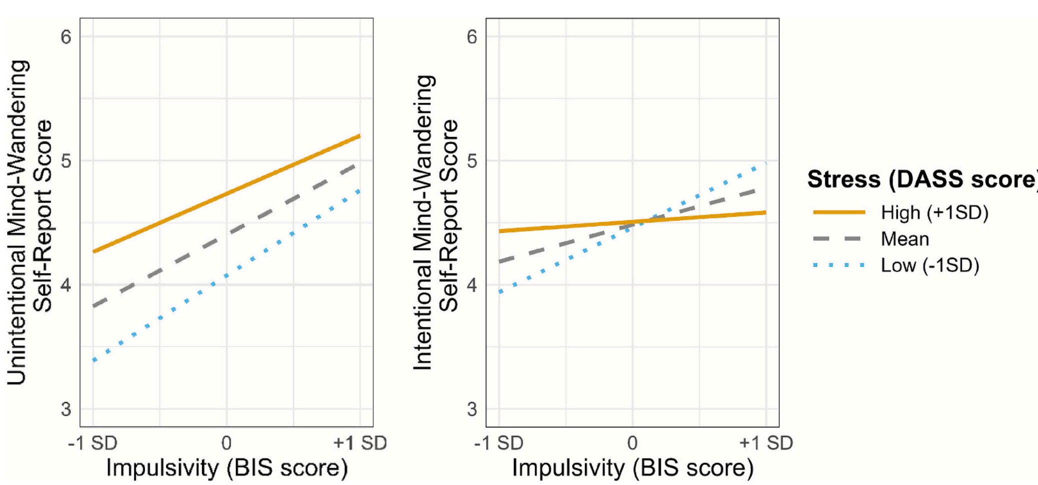

Fig. 3. Illustration of the simple slopes analysis of the self-reported intentional and unintentional mind-wandering scores at low and high stress and impulsivity, for Study 2.

from Study 1 (required $N = 255$; initially pre-registered 182). Recruitment was however halted early, due to a change in access to Inquisit online testing software. Importantly, the final sample of 157 participants was still powered to detect a small to moderate effect of $r = 0.25$ ($\alpha = 0.05$, $1\text{-}\beta = 0.90$, two-tailed), which is in line with previous correlations between impulsivity and attentional capture ($r = 0.25$; Albertella et al., 2020), and with mind-wandering ($r = 0.27$; Arabacı & Parris, 2018).

4.2. Materials

4.2.1. RSVP task with thought probes

The RSVP task was nearly identical to that used in Study 1, though participants searched only for green target letters to remove this source of heterogeneity. The key change to the Study 3 RSVP was the inclusion of mind-wandering thought probes during the task and recalled mind-wandering reports after each block.

4.2.2. Mind-wandering thought probes

During the RSVP task, an additional six thought probes were presented randomly throughout each block (18 total). These were presented at the end of additional inserted 14-letter RSVP trials with no target or distractor. The probes asked, "Immediately before this screen appeared, where was your attention focused". Participants then selected between three options, "On the task", "Intentionally mind-wandering", and "Unintentionally mind-wandering" (based on Seli et al., 2016). The outcome variables were the average percentage participants reported unintentionally and intentionally mind-wandering.

Prior to the task, participants were given the following definitions of intentional mind-wandering: "deliberately thinking about something completely unrelated to the task because you voluntarily chose to think about it"; and unintentional mind-wandering: "spontaneously thinking about something completely unrelated to the task, as your attention involuntarily drifted away, even though you were trying to focus on the task". On-task thoughts were defined as: "focus on completing the task and not thinking about anything unrelated to the task. Some examples of ON-TASK thoughts include thoughts about your performance, about the letters/colours, or about your response."

4.2.3. Recalled mind-wandering

In addition to the thought probes, at the end of each of the three blocks of the RSVP task, participants were asked to recall what percentage of the time their mind wandered away from the task to other thoughts during the previous block. Responses were along a sliding 0%–100% continuous scale. Using a second continuous scale, participants then reported what percentage of the time this mind-wandering had been completely unintentional. The recalled percentage time spent unintentionally and intentionally mind-wandering was then computed from these two responses after each block, and averaged across the three blocks.

4.3. Procedure

Participants accessed the study through an online Inquisit software link. After providing informed consent, participants completed the example block and practice block (1.9% of participants repeated either the example or practice block more than once), before completing the RSVP task with additional thought probes. They then completed the DASS-21, BIS-11, S-MW and D-MW in a random order. Finally, participants completed demographic questions.

4.4. Results

As in Study 1, The RSVP data were analysed using the identical GLMM analysis used in Study 1 with individual trial-level accuracy as the outcome variable, rather than pre-registered linear regression, correlation, and ANOVA analyses. Analysis of skewness and kurtosis scores revealed that the target-matching attentional capture index was positively skewed. Therefore, 95% confidence intervals (1000 iterations) were computed using the identical methods as Study 1. Internal reliability of all self-report measures was high (Table 4).

A preliminary GLMM analysis confirmed that identification at Lag2 for target-matching distractors was lower than Lag6 (Table 5). For target-mismatching distractors, however, there was a reverse effect with higher identification at Lag6. The split-half correlation analyses revealed a moderate to large Spearman-Brown (r_{sb}) correlation between contrasts for target-matching distractors, and a small non-significant correlation for target-mismatching distractors.

4.4.1. Impulsivity × stress interaction model in attentional capture

The results partially replicated Study 1. Both stress, $\beta = 0.01$, $CI_{bootstrapped}$ [−0.13, 0.15], impulsivity, $\beta = -0.03$, $CI_{bootstrapped}$ [−0.17, 0.12], and their interaction, $\beta = -0.01$, $CI_{bootstrapped}$ [−0.14, 0.11], were non-significant predictors of overall target identification probability. As before, stress also significantly interacted with the target-distractor lag to predict a lower level of target identification, $\beta = -0.12$, $CI_{bootstrapped}$ [−0.21, −0.03], thus replicating the relationship between stress and lower attentional capture. However, impulsivity no longer interacted with target-distractor lag, $\beta = -0.03$, $CI_{bootstrapped}$ [−0.12, 0.07], and the three-way interaction was also non-significant, $\beta = 0.04$, $CI_{bootstrapped}$ [−0.03, 0.12] (Fig. 4).

To assess the variation in attentional capture at different levels of stress, and to assess its invariance across impulsivity levels, the follow-up simple slopes analysis contrasted attentional capture across low and high levels of both stress and impulsivity. Whilst the overall interaction between stress and lag was significant, this did appear to be driven more by effects at low impulsivity levels. At low impulsivity, high stress levels were associated with a smaller difference between lags, $M_{Lag2} = 0.72$, $SE = 0.03$, $M_{Lag6} = 0.82$, $SE = 0.03$, $\log OR = -0.55$, 95% $CI_{bootstrapped}$ [−0.79, −0.31], $d = -0.30$, relative to low stress levels, $M_{Lag2} = 0.71$, $SE = 0.03$, $M_{Lag6} = 0.86$, $SE = 0.02$, $\log OR = -0.88$, 95% $CI_{bootstrapped}$ [−1.07, −0.70], $d = -0.48$, with the difference between these contrasts being significant, $\log OR = 0.33$, 95% $CI_{bootstrapped}$ [0.04, 0.62], $d = -0.18$. At high levels of impulsivity, high stress levels were still associated with lower difference between lags, $M_{Lag2} = 0.70$, $SE = 0.02$, $M_{Lag6} = 0.81$, $SE = 0.02$, $\log OR = -0.60$, 95% $CI_{bootstrapped}$ [−0.78, −0.43], $d = -0.33$, relative to low stress levels, $M_{Lag2} = 0.71$, $SE = 0.04$, $M_{Lag6} = 0.83$, $SE = 0.02$, $\log OR = -0.74$, 95% $CI_{bootstrapped}$ [−1.10, −0.40], $d = -0.41$, however the difference was weaker at this level of impulsivity with the difference in contrasts becoming non-significant, $\log OR = 0.14$, 95% $CI_{bootstrapped}$ [−0.20 0.49], $d = -0.08$. Despite showing a similar numeric pattern to Study 1, the non-significance of the interaction between impulsivity and lag, and the three-way interaction with stress, reveals that stress was a more consistent predictor of the attenuation of attentional capture across studies.

Repeating the GLMM analysis with the target-mismatch target identification revealed no significant effect of stress or impulsivity on target identification probability, $\beta < 0.11$, all confidence intervals inclusive of zero. Whilst the interaction between target-distractor lag and stress was non-significant, $\beta = -0.04$, 95% $CI_{bootstrapped}$ [−0.18, 0.14],

Table 4
Descriptive statistics and Cronbach's alpha statistics for all self-report measures in Study 3. Descriptives reflect average score (rather than sum), to gauge position on response scale. BIS (response range: 1–4), DASS (response range: 0–3), S-MW and D-MW (response range: 1–7).

	Mean	SD	Cronbach's α
BIS-11 total	2.25	0.39	0.86
DASS stress	1.12	0.67	0.86
DASS total	0.93	0.62	0.94
S-MW	4.88	1.34	0.82
D-MW	4.77	1.52	0.87

Table 5
Contrasts between Lag2 and Lag6 distractor conditions for target-matching and mismatching distractors in Study 3, as well as split-half reliability analyses of these contrasts. CI = confidence interval; LB = lower bound; UB = upper bound. Standard errors in parantheses.

		Estimated Detection Probability			Attentional Capture Index			Split-half reliability	
	Distractor condition	No distractor	Lag2	Lag6	χ^2	*p*-value	Cohen's d	r_{sb}	95% CI[LB, UB]
Study 2	No distractor	0.86 (0.01)	–	–	–	–	–	–	–
	Target-matching	–	0.71 (0.01)	0.83 (0.02)	304.66	< 0.001	−0.39	0.57	[0.46,0.66]
	Target-mismatching	–	0.86 (0.01)	0.85 (0.01)	4.69	0.030	0.05	0.14	[−0.09, 0.34]

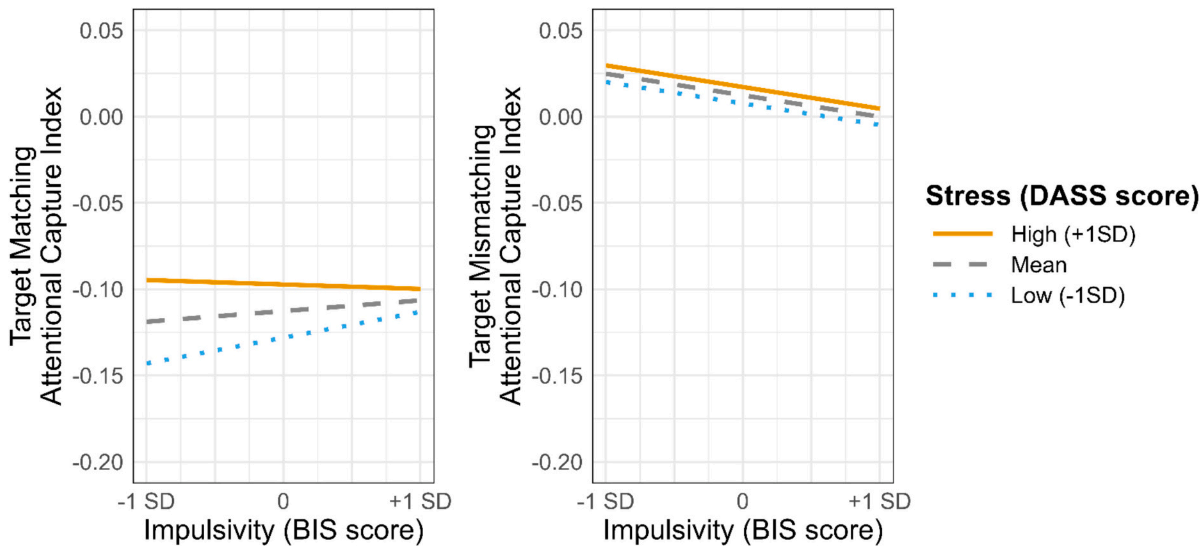

Fig. 4. Illustration of the simple slopes analysis of the average attentional capture index (difference between Lag2 and Lag6 accuracy) for target-matching and mismatching distractors at low and high stress scores and impulsivity scores, for Study 3.

in a change from Study 1's results, impulsivity positively related to a difference between Lag2 and Lag6, $\beta = 0.11$, 95% $CI_{bootstrapped}$ [0.02, 0.21]. The three-way interaction was, however, non-significant $\beta = -0.01$, 95% $CI_{bootstrapped}$ [−0.09, 0.08] (Fig. 4).

Follow-up simple slopes analysis to assess the variation in attentional capture (Lag2 versus Lag6) at different levels of impulsivity (at the average level of stress), revealed that rather than impulsivity relating to attentional capture, it related to a priming effect. Whereby there was actually higher probability of correct target identification after Lag2 versus Lag6 for low impulsive participants, $M_{Lag2} = 0.88$, SE = 0.01, $M_{Lag6} = 0.85$, SE = 0.02, logOR = 0.20, 95% $CI_{bootstrapped}$ [0.02, 0.37], d = 0.11, relative to high impulsive participants who exhibited no significant difference between the two target-distractor lags, $M_{Lag2} = 0.86$, SE = 0.01, $M_{Lag6} = 0.85$, SE = 0.01, logOR = −0.02, 95% $CI_{bootstrapped}$ [−0.15, 0.12], d = −0.01. Contrasting the magnitude of the capture effects confirmed that the priming effect was significantly greater at low impulsivity, logOR = 0.22, 95% $CI_{bootstrapped}$ [0.002, 0.44], d = −0.12. Thus, low impulsive individuals may have utilised the irrelevant distractors as target onset cues.

4.4.2. Testing whether mind-wandering mediates effects on attentional capture

Based on the initial finding that impulsivity and stress related to lower attentional capture in Study 1, it was hypothesised that this was due to impulsivity and stress causing increased mind-wandering, which reduced processing of the external distractors (see pre-registration https://osf.io/jmhct). It was therefore predicted that higher impulsivity and stress would indirectly predict lower attentional capture when mediated through mind-wandering (with probe-caught and recalled mind-wandering combined as a composite). This registered mediation analysis was, however, underpowered based on the final sample, but is reported for transparency. This mediation analysis was run using the *lavaan* R package (Rosseel, 2012), and for simplicity and to match the pre-registration attentional capture was modelled as the difference between the average accuracy between Lag2 and Lag6, rather than trial-level accuracy. Two mediation models were run, one with target-matching attentional capture as the outcome, the second with target-mismatching attentional capture as the outcome.

To confirm that the different mind-wandering measures were suitable for data reduction to distinct intentional and unintentional mind-wandering components, a Principal Components Analysis (PCA) was conducted on the standardised data with orthogonal Varimax rotation. This rotation was applied rather than the initially pre-registered Direct Oblimin rotation, due to its suitability for reduction of mind-wandering data into distinct components (see Konu et al., 2021 for similar procedure). Parallel analysis with simulated 95% breakpoint indicated two components were suitable for extraction. As expected, one reflected intentional mind-wandering and one reflected unintentional mind-wandering (see Table 6). To create a composite score for each

Table 6
Average levels of mind-wandering across all measures, and Varimax rotated PCA component eigenvalues and loadings.

Mind-wandering Measure	Average score (SD)	Intentional Component	Unintentional Component
Probe intentional	11.54% (13.02)	**0.90**	0.02
Probe unintentional	19.84% (14.73)	−0.02	**0.89**
Recall intentional	13.08% (13.32)	**0.89**	0.05
Recall unintentional	22.05% (17.83)	0.12	**0.87**
Eigenvalues	–	1.46	1.36
Proportion variance	–	40%	39%

component the probe-caught and recalled mind-wandering scores were standardised as *Z*-scores, and then averaged into separate intentional and unintentional mind-wandering scores (see Smithson et al., 2024 for discussion of this approach).

The first mediation analysis for target-matching distractors revealed that stress predicted a higher composite unintentional mind-wandering score, $\beta = 0.21$, $CI_{bootstrapped}$ [0.02, 0.39], but did not significantly predict the composite intentional mind-wandering score, $\beta = 0.06$, $CI_{bootstrapped}$ [−0.11, 0.23]. Impulsivity on the other hand predicted significantly higher levels of both unintentional mind-wandering, $\beta = 0.24$, $CI_{bootstrapped}$ [0.08, 0.40], and intentional mind-wandering, $\beta = 0.21$, $CI_{bootstrapped}$ [0.05, 0.37]. Though the initial path from stress to unintentional mind-wandering was significant, the indirect path to target-matching attentional capture was non-significant, $\beta = -0.01$, $CI_{bootstrapped}$ [−0.05, 0.02]; similarly, there were no significant indirect effects to target-matching attentional capture for impulsivity though either unintentional mind-wandering, $\beta = -0.01$, $CI_{bootstrapped}$ [−0.06, 0.03], or intentional mind-wandering, $\beta = -0.02$, $CI_{bootstrapped}$ [−0.06, 0.02]. Additionally, neither unintentional mind-wandering, $\beta = -0.05$, $CI_{bootstrapped}$ [−0.24, 0.13], or intentional mind-wandering, $\beta = -0.11$, $CI_{bootstrapped}$ [−0.26, 0.04], predicted attentional capture. The second mediation model with attentional capture from target-mismatching distractors revealed no significant direct or indirect effects, $\beta < 0.16$, all 95% confidence intervals included zero.

4.4.3. *Impulsivity × stress interaction model in mind-wandering*

The measurement of mind-wandering does however allow the test of the initial hypothesis that impulsivity and stress interact to predict heightened distraction, but with distraction by internal thoughts from unintentional mind-wandering, rather than attentional capture. This unregistered linear model analysis was conducted using the *lm* function from the *stats* R package, to assess whether stress and impulsivity interacted to predict variation in the composite mind-wandering score for both intentional and unintentional mind-wandering (Fig. 5). Bootstrapped 95% confidence intervals (1000 iterations) were computed for using the *confint* function from the R *stats* package. For unintentional mind-wandering, as with the mediation model, both impulsivity, $\beta = 0.24$, $CI_{bootstrapped}$ [0.07, 0.41], $\eta p2 = 0.05$, and stress, $\beta = 0.21$, $CI_{bootstrapped}$ [0.04, 0.37], $\eta p2 = 0.04$, predicted higher unintentional mind-wandering. The interaction between these factors was, however, non-significant, $\beta = -0.01$, $CI_{bootstrapped}$ [−0.16, 0.14], $\eta p2 < 0.01$ (Fig. 5).

For intentional mind-wandering, impulsivity was positively associated with this composite score, $\beta = 0.21$, $CI_{bootstrapped}$ [0.04, 0.20], $\eta p2 = 0.04$, whilst stress was a non-significant predictor, $\beta = -06$, $CI_{bootstrapped}$ [−0.11, 0.24], $\eta p2 < 0.01$. The interaction term was also non-significant, $\beta = -0.06$, $CI_{bootstrapped}$ [−0.21, 0.09], $\eta p2 < 0.01$.

4.5. *Discussion*

Study 3 revealed that, again, there was no evidence that stress amplified attentional capture or unintentional mind-wandering in high impulsive individuals. It also replicated evidence that stress attenuated attentional capture by target-matching distractors. A mediation analysis, however, found no evidence that this attenuation was due to increased high levels of mind-wandering.

An exploratory analysis did reveal though that both stress and impulsivity positively related to increased unintentional mind-wandering during the RSVP task, indicating that these factors weren't related to enhanced attentional control due the task, thus discounting this interpretation for the attenuated capture.

5. General discussion

Against the initial hypothesis there was no evidence that stress amplified failures in attentional control in trait-impulsive individuals. Instead, it appeared that stress and impulsivity both independently predicted greater inattention, as reflected by increased unintentional mind-wandering and attenuated attentional capture by stimuli which overlapped with the current search goal target features.

The rationale for the stress amplification hypothesis was that the increased susceptibility to lapses in attentional control in impulsive individuals may result in them being less able to regulate negative emotions, and therefore sensitive to the additional stress-induced impairments to attentional control, which would further exaggerate the initial impairment.

In the current investigation, unintentional mind-wandering was the attentional measure which most clearly reflects a failure of attentional control, as participants' task-irrelevant thoughts gain attention despite attempted to focus on a competing task. When this was measured, both during the RSVP task and with self-report scales, it was found that impulsive individuals exhibited elevated levels of unintentional mind-wandering regardless of their current level of stress, and at high levels of stress all individuals experienced a similar level of increased unintentional mind-wandering.

The current findings are therefore consistent with earlier proposals that heightened stress independently contributes to impulsive behaviours through distinct mechanisms to other non-affective impulsive traits (Cyders & Smith, 2007; Smith et al., 2007). In support of this, several large-scale Ecological Momentary Assessment (EMA) studies

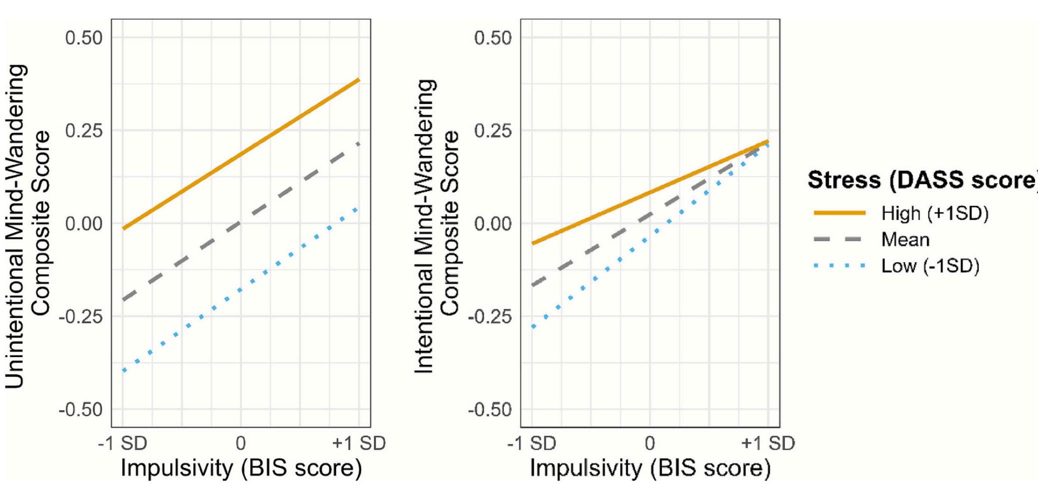

Fig. 5. Illustration of the simple slopes analysis of the average intentional and unintentional mind-wandering composite scores (average of z-scored recalled and probe-caught mind-wandering) at low and high stress and impulsivity, for Study 3.

have found that trait impulsivity does not interact with current emotional state to predict impulsive behaviours, in terms of non-planning, lack of perseverance, and self-control (Feil et al., 2020; Racine et al., 2024; Sperry et al., 2021). The current results replicate and extend these findings by demonstrating the independent effects are also true of impulsivity-linked lapses in attention.

The specific independent mechanisms will require further investigation, however, evidence has suggested that mind-wandering can be separately determined by failures in inhibitory control and the affective content of competing thoughts (Robison et al., 2017). Given that impulsivity is linked to impaired inhibitory control, high impulsive individuals may experience unintentional mind-wandering due more to the inability to suppress irrelevant thoughts which spontaneously capture attention (Aichert et al., 2012). Stress on the other hand may cause unintentional mind-wandering more through the affective value of competing off-task thoughts (i.e., worry), which are automatically prioritised over less valued on-task thoughts (Robison et al., 2017).

Interestingly, impulsivity and stress did interact when predicting attentional capture by target-matching distractors in the RSVP task in Study 1; however, this did not reflect evidence of amplification. Instead, the interaction was more consistent with high levels of stress obscuring the influence of impulsivity on attention. At low levels of stress high impulsive individuals were significantly more likely to experience an attenuation of attentional capture by target-matching distractors versus low impulsive individuals. Conversely at high levels of stress this difference between low and high impulsivity became smaller and non-significant. This was partially replicated in Study 3, with only stress predicting lower attentional capture.

Though unexpected, the finding that impulsivity correlated with attenuated attentional capture, rather than increased capture, is actually consistent with research by Landau et al. (2012). Within this study, task-relevant cues which reliably predicted target onset captured attention less in impulsive individuals, whilst irrelevant non-predictive cues captured attention more. Thus, whilst impulsivity results in heightened distraction by entirely task-irrelevant stimuli, it may result in decreased attentional allocation to features or locations more related to a task which they are attending to.

It is difficult to test whether target-mismatching stimuli capture attention more for impulsive and stressed individuals, as there was no evidence of attentional capture by these stimuli, and there was evidence of priming in Study 2 which covaried with impulsivity. This may be due to the task selected, as previous evidence suggests stimulus-driven attentional capture by peripheral target-mismatching stimuli is suppressed in this task (Folk et al., 2002). Additionally, the lack of capture could also be due to the low reliability of target-mismatch capture, as split-half correlations were very weak in this condition (Hedge et al., 2018). Future research exploring the link between impulsivity and attentional capture by target-mismatching distractors should aim to use more reliable measures of this form of attentional capture.

The hypothesised reason for the attenuated attentional capture by target-matching distractors was that stress and impulsivity increased inattention, which reduced external distractor processing. In support of this hypothesis, direct evidence has revealed attenuated attentional capture in RSVP tasks in those reporting more frequent off-task thoughts and higher trait mind-wandering, consistent with the current findings (Thomson et al., 2015). It should be noted, however, that there was no evidence that mind-wandering mediated the effect of stress or impulsivity on attentional capture when it was analysed as an average difference score. Further, mind-wandering did not directly correlate with attentional capture in the mediation model or zero-order correlations (see Supplementary materials 2).

One potential reason may be that the measure of mind-wandering didn't capture the form of inattention causing the attenuated processing of target-matching distractors. Specifically, the mind-wandering score was composed of recalled and probe-caught mind-wandering, as operationalised as a binary off-task/on-task distinction. This composite mind-wandering measure may, therefore, be more reflective of ‘zoning out’, which reflects the more complete decoupling of attention from ongoing tasks without meta-awareness. It is possible that the form of inattentive mind-wandering which relates to attenuated distractor processing occurs when participants ‘tune out’, where they are aware that their attention is disengaged but are still visually processing external stimuli (Smallwood et al., 2008; Welhaf et al., 2024). Therefore, whilst stress and impulsivity may correlate with mind-wandering, the current mind-wandering measure may not reflect the aspect of mind-wandering that caused the attenuation of attentional capture. Further, the composite mind-wandering indices were created using simple PCA data reduction of a small set of variables, a more comprehensive factor analysis of multiple varied mind-wandering measures may reveal other dimensions of mind-wandering with different relationships.

Alternatively, the disruption of visual attentional processing and mind-wandering may operate separately despite both being predicted by impulsivity and stress. For instance, stress, which was the more consistent predictor of attenuated attentional capture, has been found to disrupt top-down working-memory resources (Moran, 2016), which have been found to covary with top-down driven attentional capture by target-matching distractors in a similar RSVP task (Zhong et al., 2024). Thus, stress may interfere with target representations in working memory which are required for top-down attentional capture by target-matching stimuli (Folk et al., 2002).

It should be noted, however, that the null effects could also be due to measurement error obscuring some relationships. Indeed, as well as being underpowered, the sample in which attentional capture and mind-wandering were measured concurrently (Study 3), data was collected online over a 2-year period without set testing times. This would increase the error variance, relative to Study 1 which was conducted in two fixed sessions. Within Study 3, the individual differences in attentional capture were weaker than Study 1, and impulsivity became non-significant.

As well as attentional capture and unintentional mind-wandering, intentional mind-wandering was also measured. This is less indicative of failures of attentional control, and reflects the voluntary disengagement of attention from external stimuli. Interestingly, this measure of attention was more strongly linked to impulsivity across Study 2 and 3, for both task-concurrent and self-reported mind-wandering; and was only linked to stress in Study 2 at low levels of impulsivity.

Intentional mind-wandering can occur for a range of reasons but is often due to a lack of engagement or motivation with an external task (Robison & Unsworth, 2018). This may be especially pronounced in impulsive individuals who are more likely to experience boredom when an external task isn't engaging (Dahlen et al., 2004). Consistent with this hypothesis, Kruger et al. (2020) found that individuals who reported more severe problem gambling behaviour (and were likely more impulsive) also reported more deliberate mind-wandering during a repetitive attention task, but not an engaging gambling task.

5.1. Limitations and future directions

The current attentional capture task used neutral irrelevant stimuli to assess general distractibility. However, evidence shows that impulsivity correlates more with interference from affective/reward associated distractors (Coskunpinar & Cyders, 2013). Future research should therefore explore whether stress can amplify attentional capture by more affective external distractors.

Within the current investigation there was no interaction between stress and trait non-affective impulsivity, however, some evidence has suggested stress/arousal may interact specifically with trait negative urgency to predict higher impulsive behaviours (Herman et al., 2023; Owens et al., 2018; Pearlstein et al., 2019). It should be noted, however, that this previous evidence has been inconsistent (Pearlstein et al., 2022; Racine et al., 2024), and in Study 1 where the UPPS-P scale was measured, re-analysis with negative urgency rather than non-affective impulsivity revealed a non-significant interaction which numerically was more consistent with attenuation, not amplification ($p > .072$; Supplementary materials 3). Further research is therefore still required to uncover how all aspects of trait-impulsivity interact with affective states.

Finally, an opportunity sampling approach was taken to maximise the available sample. This, however, resulted in a predominantly young, female, undergraduate sample. Evidence suggests that there are sex differences in impulsivity, with male participants often exhibiting more risk-taking and sensation seeking behaviour (Cross et al., 2011). Future research should aim to explore the current findings in a more generalisable sample.

6. Conclusion

The current results demonstrate that impulsive individuals are prone to lapses in attentional control, but that this is not amplified by recent levels of stress. Instead, evidence revealed that impulsivity and stress independently predicted measures of inattention. Such findings have the potential to inform models of impulsivity, and uncover how mechanisms of attention required for long-term adaptive goal pursuit can become impaired.

CRediT authorship contribution statement

Chris R.H. Brown: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares no financial or non-financial conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2026.113662.

Data availability

All data and code are available via the Open Science Framework: https://osf.io/quzpd/

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