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Dispositional mindfulness and the wandering mind: Implications for attentional control in older adults

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Age-related cognitive decline brings decreases in functional status. Dispositional mindfulness, the tendency towards present-moment attention, is hypothesized to correspond with enhanced attention, whereas mind-wandering may be detrimental to cognition. The relationships among mindfulness, task-related and task-unrelated thought, and attentional control performance on Go/No-Go and Continuous Performance tasks were examined in older adults. Dispositional mindfulness was negatively associated with task-unrelated thought and was positively associated with reactive control, but not proactive control or Go/No-Go performance. Although mind-wandering was not directly associated with performance, task-unrelated thought mediated the mindfulness-proactive control relation. Fewer task-unrelated thoughts were associated with lower proactive control. Interestingly, this effect was moderated by working memory such that it was present for those with low-average, but not high, working memory. This study highlights the importance of dispositional mindfulness and mind-wandering propensity in accounting for individual differences in attentional control in older adults, providing important targets for future cognitive remediation interventions.

1. Introduction

Dispositional mindfulness is defined as the tendency to engage in receptive attention to and awareness of current experiences with non-judgment and acceptance (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006; Brown & Ryan, 2003; Kabat-Zinn, 2003). Theoretical models of mindfulness propose that the ability to attend to events as they occur, and the resulting increased attentional control, are important components of the mindfulness construct (Dreyfus, 2011; Hölzel et al., 2011). As such, there has been a burgeoning interest in examining the relationship between mindfulness and attentional control across various populations including adolescents (Oberle, Schonert-Reichl, Lawlor, & Thomson, 2011), college undergraduates (Ainsworth, Eddershaw, Meron, Baldwin, & Garner, 2013; Anicha, Ode, Moeller, & Robinson, 2012; Cheyne, Carriere, & Smilek, 2006; Quaglia, Goodman, & Brown, 2015; Quickel, Johnson, & David, 2014; Schmertz, Anderson, & Robins, 2009), community adults (Galla, Hale, Shrestha, Loo, & Smalley, 2012; Moore & Malinowski, 2009; Rosenberg, Noonan, DeGutis, & Esterman, 2013; Ruocco & Direkoglu, 2013), older adults (Fiocco & Mallya, 2015; Prakash, Hussain, & Schirda, 2015), and clinical populations with attentional deficits (e.g., Tabak, Horan, & Green, 2015; Zylowska et al., 2008). Aging

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samples are ideal for studying this link between mindfulness and cognition as these individuals exhibit well-characterized deficits in attentional control that are implicated in critical functions such as comprehending medical information (Park, 1999; Zwahr, Park, Eaton, & Larson, 1997), emotion regulation abilities (Mather & Carstensen, 2005; Mather & Knight, 2005), and overall well-being (Kryla-Lighthall & Mather, 2009). Further, given the aging of the baby boomer generation, this information has the potential to characterize probable risk and protective factors contributing to individual differences in cognitive decline across development as well as identify targets for the use of mindfulness as a cognitive remediation intervention. Thus, the present study was designed to examine whether mindfulness relates to individual differences in attentional control in this population.

Although the use of mindfulness training to augment attention has shown promise (see Chiesa, Calati, & Serretti, 2011 for review), investigations into the relationship between trait mindfulness and attentional control are only beginning to emerge in older-adult samples, with inconsistent findings between the two existing studies (Fiocco & Mallya, 2015; Prakash et al., 2015). Prakash et al. (2015) assessed attentional control by employing higher-order executive functioning tasks of working memory, inhibitory control, and task-switching. Examining the associations among interference measures on these tasks and dispositional mindfulness assessed using the Mindful Attention and Awareness Scale (MAAS; Brown & Ryan, 2003), this study failed to find support for a positive link between dispositional mindfulness and metrics of attentional control in either young or older adults. In contrast, Fiocco and Mallya (2015) found a positive association in older adults between scores on the MAAS and set-shifting on Trail Making Test B as well as marginal associations with simple attention and processing speed on Trail Making Test A and shifting cost calculated by subtracting performance on the two tasks (Fiocco & Mallya, 2015). Potential sources of these discrepancies include the lengthier task duration and computerized administration in the study by Prakash et al. (2015) as compared to the brief, paper-and-pencil measures employed by Fiocco and Mallya (2015). In the context of this limited, mixed literature the present study will provide further insight into whether and how mindfulness is related to attention in an aging sample.

Interestingly, there is emerging evidence that mind-wandering (MW), a shift in attention away from external tasks and towards internal thought (Smallwood & Schooler, 2006), mediates the relation between mindfulness and attentional control (Cheyne, Solman, Carriere, & Smilek, 2009; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Mrazek, Smallwood, & Schooler, 2012). Mrazek et al. (2012), embedded MW probes within a Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) and found evidence for a negative association between dispositional mindfulness and MW in college undergraduates. Further, a subsequent study found that MW mediated the effect of brief mindfulness training on SART performance (Mrazek et al., 2013). Extending these findings to an aging sample, Frank, Nara, Zavagnin, Touron, and Kane (2015) recently examined the links among mindfulness and different types of MW in older adults. Categorizing MW into task-unrelated thoughts (TUT) and task-related interference (TRI), they found evidence for differential associations among various facets of mindfulness and the two functionally distinct types of MW. Specifically, employing the Five Facet Mindfulness Questionnaire (Baer et al., 2006), this study found that the Describing Facet was negatively associated with TUT, whereas the Observing Facet was positively associated with TRI. Interestingly, Observing mediated the relationship between age and TRI, suggesting that the higher levels of TRI reported by older adults were partially explained by an increased tendency to observe their surroundings. These findings suggest that TRI and TUT may have unique relations with mindfulness within older adults, although the ramifications of MW for performance were not examined in that study. The present study will build upon the existing literature by examining whether the tendency to engage with internal mentation accounts for the link between mindfulness and attentional control in older adults.

The present study evaluated attentional control using a Go/No-Go task and a Continuous Performance Task (CPT) that allowed for assessment of proactive (i.e., preparatory attention) and reactive (i.e., post-stimulus correction) control. We were particularly interested in these specific strategies given that there is evidence of an age-related shift from reliance on proactive to reactive strategies (Braver, Satpute, Rush, Racine, & Barch, 2005; Braver et al., 2001; Bugg, 2014). Self-reported MW probes were embedded within each task. Although previous examinations of trait mindfulness and attentional control are mixed, we hypothesized that mindfulness would be negatively associated with TUT and TRI and positively associated with performance on both tasks. We also predicted that TUT and TRI would be negatively associated with performance on both tasks. Extending previous findings from young adults (Mrazek et al., 2013), we hypothesized that MW would mediate the association between mindfulness and attentional control on both tasks. Of note, this study used cross-sectional data from a larger randomized controlled trial in which working memory was examined as a moderator of mindfulness training's effects. The present study examined the exploratory hypothesis that individual differences in working memory would moderate the relationship between MW and attentional control. This prediction was based on evidence that working memory predicts errors, reaction time variability, and TUT during a Go/No-Go task (McVay & Kane, 2009), as well as meta-analytic evidence that individuals with fewer cognitive resources are more likely to engage in TUT, while those with more resources engage in more TRI (Randall, Oswald, & Beier, 2014). Notably, this meta-analysis did not include studies of older-adult samples, a population with marked declines in working memory abilities. We hypothesized that individuals with high working memory would show a stronger negative relationship between MW and performance than those with lower working memory.

2. Methods

2.1. Participants

The data reported in this manuscript were collected in the context of a parent study designed to examine the influence of mindfulness training, as compared to an active nutrition education control, in reducing MW and enhancing attentional control in older adults. The broader study was advertised as a "Health and Lifestyle Education Study," and aspects common to each intervention were described on advertisement fliers to reduce participant expectancy biases. The phrases "mindfulness" and "meditation" were purposefully omitted from all recruitment materials to minimize potential demand characteristics (Boot, Blakely, & Simons, 2011). The current study utilized pre-intervention data collected on 75 older adults. Participants provided demographic information including age, gender, and years of education. All participants were required to meet the following inclusionary criteria: between 60 and 74 years old; a score >23 on the Mini-Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975); a score $\leqslant$10 on the Geriatric Depression Scale (GDS; Parmelee, Lawton, & Katz, 1989); a minimum corrected near and far acuity of 20/40; absence of color blindness; no previous exposure to mindfulness training, meditation, or yoga; native English speaker; no history of self-reported psychiatric or neurological disorders or chronic inflammatory diseases; no regular use of psychiatric medication. All participants provided written informed consent before participating in accordance with the protocol approved by The Ohio State University Institutional Review Board.

2.2. Materials

2.2.1. Mindful Attention Awareness Scale

The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) was used to assess dispositional mindfulness. The MAAS is widely used to measure attention to and awareness of current experiences and has previously been used in older-adult samples (Morone, Greco, & Weiner, 2008). Participants rated their experience of each item using a six-point Likert scale (1 = almost always, 6 = almost never). An example item is: "I rush through activities without really being attentive to them." This single-factor questionnaire has 15 items and has demonstrated good internal consistency and validity (Brown & Ryan, 2003). Cronbach's alpha was 0.799 in this study.

2.2.2. Mind-wandering thought probes

Self-report MW probes were used as a measure of within-task MW during both cognitive tasks. Probes were presented at quasi-random intervals (see task descriptions for details). Many probes used in prior studies assessed on- vs. off-task thought, but did not include measures of TRI (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Jackson & Balota, 2012). Given the emerging evidence that older adults report less TUT, but more TRI, than young adults (McVay, Meier, Touron, & Kane, 2013), we employed an adapted version of the probes used in McVay et al. (2013) rather than those used in other studies that probed for TRI but did not administer the probes to older adults (e.g., Stawarczyk, Majerus, Catale, & D'Argembeau, 2014). Participants received extensive instructions (adapted from McVay et al., 2013) for responding to the probes that included examples for each of the three categories. For the first probe, they were asked to categorize their immediately preceding thoughts as either (1) on-task; (2) evaluating one's performance; or (3) off-task: thinking about current state of being, personal worries, daydreams, etc. Subsequently, participants were asked to enter a short description of their thought, the judgmental nature of their thought on a 5-point Likert scale, and the temporal orientation of their thought as either past, present, or future. For the purposes of the current study, only the categorical responses were used. The dependent variables of interest were the proportion of TRI (number of category 2 responses/total number of responses) and the proportion of TUT (number of category 3 responses/total number of responses).

2.2.3. Modified Go/No-Go task

This task assesses inhibitory control and sustained attention (O'Connell et al., 2009; Rubia et al., 2001). Similar paradigms have been widely used in the MW literature to examine the relationships among mindfulness, MW, and cognitive performance in young adults (Cheyne et al., 2006; Cheyne et al., 2009; Jackson & Balota, 2012; McVay & Kane, 2009; Mrazek et al., 2012; Mrazek et al., 2013). Stimuli were presented visually and consisted of two letters to which participants responded by pressing the corresponding keys on the keyboard with their right and left index fingers. Participants were asked to respond to frequent non-targets (Go trials) and to inhibit their responses if an auditory tone was presented at the same time as the visual stimulus (No-Go trials). Each trial began with a fixation cross for 750 ms followed by the stimulus for 750 ms. The task began with 1 practice block of 10 Go trials; followed by 1 practice block consisting of 10 Go trials and 3 No-Go trials; and a subsequent practice block comprised of 15 Go trials, 3 No-Go trials, and 3 probe trials. The full task had 6 blocks consisting of 63 trials each: 54 Go trials, 6 No-Go trials, and 3 probe trials. Within each block, MW probes appeared after 15 trials (22,500 ms between probes), 20 trials (30,000 ms between probes), and 25 trials (37,500 between probes) and the order of presentation within blocks was counterbalanced such that they appeared with equal frequency after 15, 20, and 25 trials across the full task. The presentation order of the 6 blocks was randomly generated. We collected response time data, as well as the number of correct responses, errors of omission, and errors of commission. The dependent variables of interest were the coefficient of variability for reaction time (RT_CV) and the signal-detection sensitivity scores (d_L).

2.2.4. Continuous Performance Task (CPT) – word version

This task assesses representation, maintenance, and updating of task goals in response to contextual cues (Paxton, Barch, Racine, & Braver, 2008; Rosvold, Mirsky, Sarason, Bransome Jr., & Beck, 1956). It has been employed in both young and older adults and forms the basis for the Dual Mechanisms of Control theory that parses cognitive control into two complementary strategies: proactive (i.e., preparatory attention) and reactive control (i.e., post-stimulus correction; Braver, 2012). Words were presented one at a time (750 ms each) in cue-probe pairs. Participants were instructed to respond YES with their dominant-hand index finger when a full target sequence was complete (referred to here as "AX" in which "A" is the target cue and "X" is the target probe) and NO with their dominant-hand middle finger for all other words. There were 70.8% "AX" trials, 12.5% "BX" trials; 12.5% "AY" trials; and 4.2% "BY" trials. Two versions of the task were employed, drawing from two lists of nouns matched on length, familiarity, and frequency (Table 1; Wilson, 1988). The use of the two versions was counterbalanced across participants. Task demand was manipulated by altering cue-probe delay duration. There were four low-demand blocks (1000 ms delay between the cue and the probe) and four high-demand blocks (5000 ms delay between the cue and the probe) with a jittered inter-trial interval such that each sequence took 7500 ms total. Data was collapsed across the two demands for the purposes of the present study. The task began with 1 long-delay and 1 short-delay practice block, each consisting of 10 cue-probe trials; followed by 1 long-delay and 1 short-delay practice block, each consisting of 10 cue-probe pairs and 3 thought probes. The full task consisted of 8 blocks with 24 cue-probe pairs and 6 thought probes each. The 4 short-delay and 4 long-delay blocks were presented in an alternating sequence (e.g., short, long, short, long, etc.). MW probes appeared after 3 (22,500 ms between probes), 4 (30,000 ms between probes), or 5 (37,500 ms between probes) cue-probe sequences, and this was counterbalanced across blocks such that they appeared with equal frequency after 3, 4, and 5 sequences in the full task. The order of each 4 blocks was randomly generated and we counterbalanced whether the task began with a short- or long-delay block across participants. The dependent variables of interest were the coefficient of variability for reaction time (RT_CV) as well as the signal-detection sensitivity score for proactive (d-proactive) and reactive control (d-reactive).

2.2.5. Working Memory Index, Wechsler Adult Intelligence Scale (WAIS-IV; Wechsler, Coalson, & Raiford, 2008)

This measure assesses the ability to memorize new information, hold it in short-term memory, and manipulate it. We administered the Digit Span and Arithmetic subtests given the availability of age appropriate norms. The Digit Span subtest measures working memory, mental manipulation, and rote memory. There were 3 Digit Span tasks: forward, backward, and sequencing. There were 8 items in each Digit Span task beginning with 2 digits and increasing to 9. The subtest was discontinued after the participant received a score of 0 on both trials of one item. The Arithmetic subtest measures mental manipulation, attention, short- and long-term memory, and numerical reasoning. Working within a specified time limit (30 s), the participant was asked to solve a series of arithmetic word problems (maximum problems = 22). The subtest was discontinued after the participant answered three consecutive trials incorrectly. The dependent variable of interest is an age-corrected working memory index score (WMI) derived from performance on the two subtests.

2.3. Statistical analyses

Data were analyzed using SPSS Version 22 (IBM Corp., 2013) supplemented by the PROCESS (Hayes, 2012) and MODPROBE macros for SPSS (Hayes & Matthes, 2009). One of the 75 older adults was excluded due to not understanding task instructions and exhibiting a low accuracy score on the No-Go trials (11% accuracy), resulting in the analysis of data from 74 participants for Go/No-Go variables. One of the 75 older adults did not complete the CPT and one participant completed the incorrect version of the CPT for their handedness, so all analyses from this task were conducted using 73 participants. Data were checked for response errors due to finger misplacement. All responses made by pressing extraneous keys that were immediately adjacent to a permitted key were corrected to reflect the intended response. Several variables were assessed for significant outliers: MAAS scores, TRI from both tasks, TUT from both tasks, RT_CV from both tasks, Go/No-Go d_L, d-proactive, and d-reactive. To do so, data was *z*-standardized and all values >|2.5| *SD* from the mean were replaced with the value corresponding to 2.5 *SD* from the mean (Osborne & Overbay, 2004). MAAS scores, TRI and TUT from both tasks, RT_CV from both tasks, and Go/No-Go d_L had significant outliers that were corrected. Only one participant had a clustering of outliers, with corrections made for TUT during the Go/No-Go task and TUT during the CPT. Each variable was checked for normality using the Shapiro-Wilk test of normality. Nonparametric statistics were conducted for analyses including non-normal variables.

Table 1
Words used in each version of the Continuous Performance Task.

	Version 1		Version 2	
	Cue	Probe	Cue	Probe
Target sequences	MYTH	TAPE	YARD	DRILL
Non-target stimuli	BENCH	GRADE	ROLL	FISH
	WASTE	KNEE	CORN	CRIME
	BONE	RICE	ALERT	BONE
	SMELL	FATE	GUIDE	GIFT
	OWNER	GOLF	CASH	FRUIT

The coefficient of variability for reaction time (RT_CV) was computed using the following formula: (*SD* of RT/Mean RT). This provides a behavioral measure of task engagement by measuring response variability independent of mean differences (Cheyne et al., 2009). Signal detection indices (d_L) were computed using the formula for logistic distributions: $d_L = \ln\{[H(1-FA)]/[(1-H)FA]\}$. The d_L for the Go/No-Go task was computed using the hit rate for Go trials and the false alarm rate for No-Go trials. The d_L for reactive control (d-reactive) was computed using the hit rate for "AX" trials and the false alarm rate for "AY" trials (Stawarczyk et al., 2014). The d_L for proactive control (d-proactive) was computed using the hit rate for "AX" trials and the false alarm rate for "BX" trials (Stawarczyk et al., 2014). The accuracy value for the probe stimulus was used in these calculations. A correction factor of ±0.001 was applied to all data in order to correct for cases of perfect hit rates (1.0) and null false-alarms (0.0). MW was separated into the proportion of TRI reported (number of category 2 responses/total number of responses) and the proportion of TUT reported (number of category 3 responses/total number of responses).

We first conducted bivariate correlations to examine the associations among all variables. We then conducted tests of simple mediation in order to test the hypothesis that MW would mediate the relationship between mindfulness and each measure of attentional control. These analyses were conducted using the PROCESS macro in which we employed the bias-corrected bootstrapping technique with 5000 bootstrapping samples to estimate the direct, total, and indirect effects of dispositional mindfulness on attentional control. This bootstrapping procedure does not assume a normally distributed indirect effect, rendering it a robust tool with which to examine such effects (Preacher & Hayes, 2004). The indirect effect in this model is the effect of trait mindfulness on attentional control (either d_L, d-proactive, or d-reactive) explained by the proportion of reported MW (either TRI or TUT), whereas the direct effect is the effect of trait mindfulness on attentional control that is not explained by MW rates and the total effect is the sum of the indirect effect and the direct effect.

Next, moderated mediation analyses were conducted in order examine the moderating effect of working memory (Hayes & Matthes, 2009). Individual WMI scores were categorized into low-average, at or below one *SD* of the standard mean (WMI $\leqslant$ 115), and above one *SD* of the standard mean (WMI > 115). Using PROCESS, we examined two criteria for moderated mediation: a moderation of at least one path in the mediation model and a conditional indirect effect in which the indirect effect was dependent on the level of the moderator (Preacher, Rucker, & Hayes, 2007). This analysis examined the interaction effects at each of three paths: the interaction between dispositional mindfulness and WMI in predicting MW, the interaction between MW and WMI in predicting attentional control, and the interaction between mindfulness and WMI in predicting attentional control. We examined the index of moderated mediation produced by PROCESS, again using the bootstrapping technique with 5000 resamples. This index assessed whether there was a non-zero weight of the moderator in the indirect effect. In all mediation and moderation analyses, point estimates were considered statistically significant if the 95% confidence intervals (CI) did not contain zero.

3. Results

3.1. Mindfulness, mind-wandering, and attentional control

Descriptive statistics for all variables are presented in Table 2. In order to examine the associations among mindfulness, MW, and indices of attentional control, two-tailed bivariate correlations were conducted for variables measured during the Go/No-Go Task and the CPT (Table 3).

Dispositional mindfulness was negatively associated with both TRI ($\rho = -0.24$, $p = 0.05$) and TUT ($\rho = -0.24$, $p = 0.04$) on the Go/No-Go task, but was only associated with TUT ($\rho = -0.27$, $p = 0.02$) on the CPT. Examining associations among mindfulness and metrics of attentional control, we found partial support for our hypotheses in that mindfulness was positively associated with d-reactive during the CPT ($\rho = 0.23$, $p = 0.05$), but it was not significantly associated with d_L on the Go/No-Go task, d-proactive on the CPT, or RT_CV on either task. These results suggest that although trait mindfulness corresponds with fewer reported MW episodes, it is related only to select domains of attentional control in older adults.

We then examined the associations between MW and behavioral performance on both tasks. The proportion of reported TRI was not associated with any performance variables on the Go/No-Go or the CPT. The proportion of reported TUT was not associated with d_L, but was associated with RT_CV on the Go/No-Go task ($\rho = 0.25$, $p = 0.03$). TUT was not associated with d-proactive, d-reactive, or RT_CV on the CPT. Contrary to our predictions, these results suggest that probe-caught MW rates are not directly associated with behavioral performance on these tasks in older adults.

3.2. The mediating role of MW

Despite the mixed findings regarding the relationships among mindfulness, MW, and attentional control, we were interested in investigating whether there might be an indirect effect of mindfulness on attentional control performance through MW. Specifically, we examined mediation models based on the significant associations among mindfulness, TUT, and TRI on the Go/No-Go task and between mindfulness and TUT on the CPT. Unstandardized beta coefficients (B) and point estimates for these simple mediation analyses are presented in Table 4.

In the Go/No-Go task there was no significant direct effect of mindfulness on d_L and no significant indirect effect through TRI or TUT. In the CPT, there was a significant total effect of mindfulness on d-reactive, point estimate = 1.121,

Table 2
Study sample demographics and characteristics.

Demographic/characteristic	Mean	SD	Range
Full sample (N = 75)			
Age	66.21	3.97	60–74
Education	16.58	2.69	12–26
Female (%)	57.33	–	–
Ethnicity (%)			
Caucasian	86.67	–	–
African American	9.33	–	–
Hispanic	1.33	–	–
Not provided	2.67	–	–
MAAS	4.43	0.62	2.89–5.73
WMI	106.39	12.91	69.00–145.00
CPT (N = 73)			
TRI	0.14	0.13	0–0.49
TUT	0.10	0.12	0–0.49
d-proactive	7.95	3.02	2.92–13.81
d-reactive	7.90	2.83	3.03–13.81
RT_CV	0.25	0.03	0.18–0.33
Go/No-Go task (N = 74)			
TRI	0.21	0.19	0–0.69
TUT	0.13	0.14	0–0.53
d_L	6.67	2.24	2.53–12.42
RT_CV	0.20	0.04	0.13–0.31

Table 3
Bivariate correlations between mindfulness disposition, mind-wandering, working memory index, and task performance.

Go/No-Go	1	2	3	4	5	6
1. MAAS	1	−0.17	−0.23*	−0.24*	−0.04	0.19
2. RT_CV		1	0.15	0.25*	−0.26*	−0.51**
3. TRI			1	0.38**	0.04	−0.16
4. TUT				1	0.15	−0.08
5. WMI					1	0.23*
6. dL						1

CPT	1	2	3	4	5	6	7
1. MAAS	1	−0.14	−0.14	−0.27*	−0.04	0.00	0.23*
2. RT_CV		1	0.01	0.17	−0.20	−0.11	−0.25*
3. TRI			1	0.34**	−0.08	−0.13	−0.07
4. TUT				1	0.16	0.16	0.00
5. WMI					1	0.28*	0.18
6. d-proactive						1	0.34**
7. d-reactive							1

Note. Go/No-Go $N = 74$, CPT $N = 73$. Higher numbers reflect (1) higher scores on the MAAS, (2) larger reaction time variability (3) higher proportion TRI, (4) higher proportion TUT, (5) higher WMI scores, (6) higher d_L (Go/No-Go) or higher d-proactive (CPT), (7) higher d-reactive.
* $p < 0.05$.
** $p \leq .01$.

Table 4
Simple mediation models for the relationship between mindfulness disposition (IV) and attentional control indices (DV) through MW (M).

Condition	DV	M	IV on M (a)	M on DV (b)	Direct effect (c′)	Total effect (c)	Indirect effect (a × b)	95% CI (a × b)
Go/No-Go	d_L	TRI	−0.049	−2.098	0.456	0.560	0.104	[−0.024, 0.496]
Go/No-Go	d_L	TUT	−0.047	−2.044	0.463	0.560	0.097	[−0.020, 0.433]
CPT	d-reactive	TUT	−0.042	0.573	1.144*	1.121*	−0.024	[−0.313, 0.180]
CPT	d-proactive	TUT	−0.042	6.510*	0.414	0.144	−0.270*	[−0.852, −0.012]*

Note. Go/No-Go $N = 74$, CPT $N = 73$. *$p < 0.05$, **$p \leq 0.01$. Point estimate values are presented for the total and indirect effects. All other values represent unstandardized beta coefficients.

95% CI [0.054, 2.187], $t = 2.095$, $p = 0.040$, but no significant indirect effect through TUT. There was a significant indirect effect of mindfulness on d-proactive through TUT, point estimate = −0.270, 95% CI [−0.852, −0.012] (see Table 4). The observed pattern of effects may be conceptualized as an inconsistent mediation, or suppression effect (MacKinnon, Krull, & Lockwood, 2000), which occurs when the direct and indirect effect are in opposing directions such that the addition of the mediator variable to the model increases the association between the independent and dependent variables. In this case, the direct effect of mindfulness on d-proactive (c′) was not significant but in the positive direction and the indirect effect of mindfulness on d-proactive through TUT was negative. Although not significant, the resulting direct effect (c′) was larger than the original total effect (c), which fits the profile of a suppression effect (MacKinnon et al., 2000). Given this pattern of results, it appears that although the effect of mindfulness alone on d-proactive was not significant and in the positive direction, B = 0.414, 95% CI [−0.851, 1.679], $t = 0.653$, $p = 0.516$, there was a stronger indirect effect of mindfulness on d-proactive when considering TUT. Higher mindfulness was a marginally significant predictor of less TUT, B = −0.042, 95% CI [−0.090, 0.007], $t = -1.697$, $p = 0.094$, and higher TUT predicted greater d-proactive, B = 6.510, 95% CI [0.919, 12.100], $t = 2.322$, $p = 0.023$, resulting in an overall negative indirect effect of mindfulness on d-proactive largely driven by TUT rates.

3.3. The moderating role of working memory

We then investigated moderated mediation for the significant mediation models outlined above in order to examine the effect of working memory (low-average WMI ⩽ 115 vs. high WMI > 115) on paths a, b, and c (Fig. 1). The overall index of moderated mediation was not significant, index = 0.720, 95% CI [−0.242, 2.511]. Of the three interactions tested, the interaction between TUT and WMI in predicting d-proactive (at path b) was the only significant effect, B = −17.100, 95% CI [−33.272, −0.927], $t = -2.111$, $p = 0.039$. The interactions between mindfulness and WMI was not significant for predicting TUT (at path a), B = −0.050, 95% CI [−0.162, 0.062], $t = -0.896$, $p = 0.373$, or for predicting d-proactive (at path c), B = 0.273, 95% CI [−2.926, 3.472], $t = 0.170$, $p = 0.865$.

Given the interaction between TUT and WMI in the above results, an exploratory moderation analysis was then conducted to directly probe this interaction (Table 5) and simple slopes analyses revealed a significant effect of TUT on d-proactive for those with low-average WMI, B = 11.413, 95% CI [5.627, 17.199], $t = 3.935$, $p < 0.001$, but not those with high WMI, B = −6.347, 95% CI [−18.140, 5.446], $t = -1.074$, $p = 0.287$. Therefore, the relationship between TUT and d-proactive is conditional upon the level of working memory such that there is a significant association between TUT rates and d-proactive, but only for individuals with low-average WMI (Fig. 2).

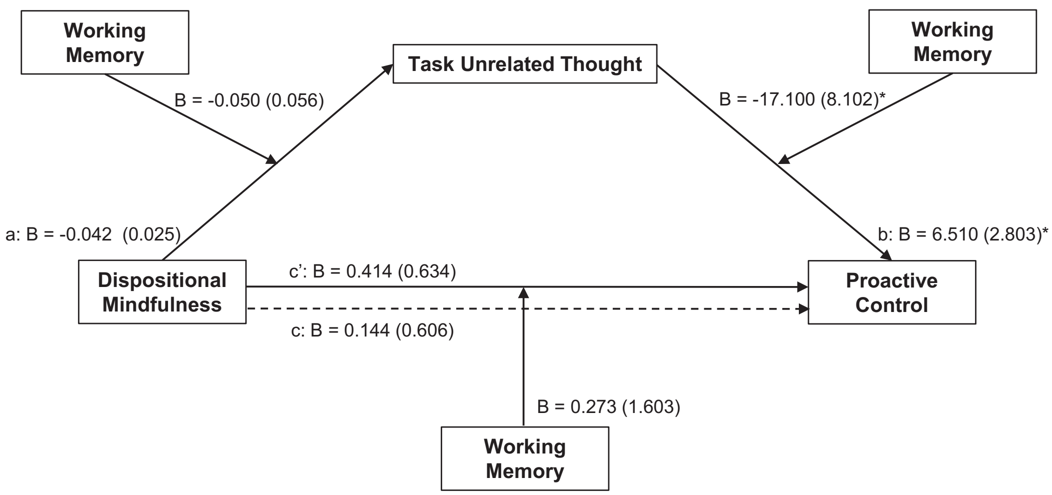

Fig. 1. $N = 73$. The exploratory model examining working memory (WMI) as a moderator in the mediated pathway in the CPT. The unstandardized coefficients with *SE* in parentheses are presented for each path. The bold line connecting dispositional mindfulness with proactive control indicates the direct effect (c′) and the dotted line indicates the total effect of mindfulness on proactive control (c). Note. $^*p < 0.05$.

Table 5
Regression output for the moderation of the relationship between task-unrelated thought and proactive control by working memory index.

	Unstandardized coefficient (B)	*SE*	*t*	*p*	95% CI
Constant	8.001	0.337	23.742	0.000	[7.333, 8.679]
TUT	6.547	2.657	2.465	0.016*	[1.248, 11.847]*
WMI	0.963	0.807	1.193	0.237	[−0.647, 2.573]
WMI X TUT	−17.759	6.585	−2.697	0.009*	[−30.895, −4.624]*

Note. N = 73. $R^2 = 0.176$, $F(3,69) = 5.817$, $p = 0.001$.
* $p < .05$.

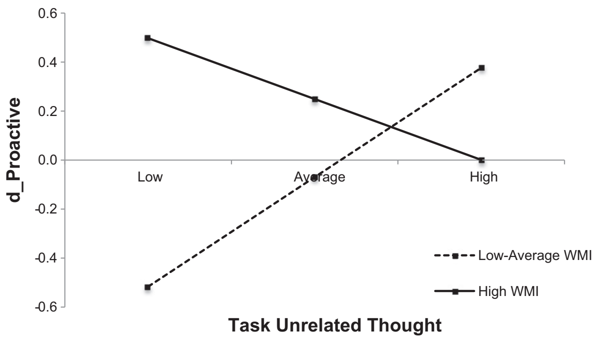

Fig. 2. The effect of TUT on proactive control during the CPT is moderated by working memory. Simple slopes analysis. "Low-Average WMI" corresponds to the effect at or below 1 *SD* of the standard mean WMI (<115), "High WMI" corresponds to the effect at 1 *SD* above the standard mean WMI (>115).

4. Discussion

Probe-caught reports of MW were collected in the context of two cognitive tasks in order to examine the relationships among mindfulness, MW, and attentional control in a community sample of older adults. These results extend previous work predominantly conducted with college undergraduates by demonstrating a negative relationship between dispositional mindfulness and MW in older adults. There were mixed findings regarding the associations between mindfulness and attentional control, with no significant findings on the Go/No-Go task and a positive association with reactive, but not proactive control on the CPT. Contrary to our predictions, as well as previous findings (Cheyne et al., 2006; Mrazek et al., 2012; Randall et al., 2014), we did not find MW to be directly associated with performance on either task. However, planned analyses revealed that TUT mediated the association between mindfulness and proactive control on the CPT. Interestingly, this mediation was driven by a strong positive effect of TUT on proactive control. Additionally, working memory was found to be a moderator of the relationship between TUT and proactive control such that there was a positive association between TUT and proactive control in those with low-average working memory, but no association for those with high working memory. Possible interpretations of these findings are discussed below.

4.1. Mindfulness and mind-wandering

In the present study, dispositional mindfulness was negatively associated with TUT on both tasks and TRI on the Go/No-Go task. These findings extend the existence of an association between mindfulness and self-reported MW in young adults (Cheyne et al., 2006; Cheyne et al., 2009; Mrazek et al., 2012) to suggest that this relationship persists in a community-dwelling sample of older adults. More specifically, our findings suggest that the tendency to attend to the present moment may be associated with less task-unrelated mentation irrespective of task type, but it is only associated with less task-related interference during the simpler of the two tasks (i.e., the Go/No-Go task, which primarily requires sustained attention; O'Connell et al., 2009; Rubia et al., 2001). However, our data are inconsistent with prior reports of a negative relationship between mindfulness and a behavioral index of task engagement, reaction time variability (Galla et al., 2012). As discussed in the limitations section, we cannot rule out insufficient power to detect this effect nor that these tasks may not have been difficult enough to produce sufficient variability in reaction times. Interestingly, there are instances in which measures of mindfulness have been found to be positively associated with specific types of MW (Andrews-Hanna et al., 2013; Frank et al., 2015), providing the possibility that thought content is a crucial delineator of the relationship between mindfulness and MW that contributes to mixed findings. Thus, future qualitative analyses might further clarify these effects.

4.2. Mindfulness and cognitive performance

Attentional control is theorized to be a primary component of mindfulness (Dreyfus, 2011; Hölzel et al., 2011). Therefore, it was hypothesized that mindfulness would be associated with sustained attention, enhanced focused attention in moments of interference (i.e., reactive control), and a preserved ability to maintain goal information and limit interference (i.e., proactive control) in older adults. We did not find a significant association between dispositional mindfulness and performance on the Go/No-Go task, suggesting that although trait mindfulness was associated with less frequent MW on that task, it was not associated with improved sustained attention. However, a more nuanced picture emerged when examining data from the CPT. We found that more mindful individuals were able to more effectively reactivate task information to resolve interference, but that there was a lack of an association between mindfulness and proactive control. We propose that mindfulness may be more robustly related to reactive control because it is better preserved than proactive control in older adults (Braver, 2012; Braver & Barch, 2002; Bugg, 2014). Moreover, we argue that both task difficulty and the cognitive resources required by the control strategies may have influenced their use. Whereas proactive control is associated with sustained prefrontal activation, reactive control only intermittently recruits those regions, suggesting smaller resource demands (Braver, 2012). In the context of low task demands, equivalent accuracy can be achieved using reactive control or the more resource-demanding proactive control, with differences only detectable in reaction times. Therefore, it may be the case that older adults may more frequently employ reactive strategies to optimize performance in the context of diminished cognitive resources and that mindfulness is associated with an enhanced ability to do so effectively.

Of note, this is not the first older-adult study to produce mixed results for the association between mindfulness and attentional control (Fiocco & Mallya, 2015; Prakash et al., 2015), and several young-adult studies that used the CPT specifically found mixed results (Galla et al., 2012; Rosenberg et al., 2013; Ruocco & Direkoglu, 2013; Schmertz et al., 2009). Notably, a recent factor analysis of five widely used mindfulness scales and six measures of attention also calls this relationship into question. This factor analysis yielded no significant shared variance between the latent mindfulness and attention factors, suggesting that either the relation between the two constructs is weak or that existing mindfulness measures do not adequately capture focused attention (Quickel et al., 2014). Along these lines, the lack of an observed association between mindfulness and proactive control may have resulted from the use of the MAAS. This unidemensional measure of mindfulness taps awareness and attention to the present moment (Brown & Ryan, 2003) which may be more closely related to reactive modes of control, identifying interference as it occurs, rather than the maintenance and flexible use of cue information that is required for proactive control. Therefore, it is important to consider that mindfulness may also be assessed as a multifaceted construct (see Baer et al., 2006) and that different aspects of mindfulness might be related to specific domains of cognition in meaningful ways (e.g., Anicha et al., 2012). Thus, future studies are needed to fully explore the link between individual differences in mindfulness and attentional control, particularly across age.

4.3. Mind-wandering and cognitive performance

Surprisingly, we did not find MW to be significantly associated with performance on the Go/No-Go task, nor was it related to proactive or reactive control on the CPT. This is in contrast to studies in young adults finding that fluctuations in MW over the course of a task correspond to changes in task performance (Galla et al., 2012; Rosenberg et al., 2013; Thomson, Seli, Besner, & Smilek, 2014) as well as a recent meta-analysis that found that off-task thought was negatively associated with performance across various tasks including the SART, a very similar paradigm to the Go/No-Go (Randall et al., 2014). However, results within aging samples are less consistent (Krawietz, Tamplin, & Radvansky, 2012; Maillet & Rajah, 2013; McVay et al., 2013). For example, one study found that although older adults reported less MW than young adults, TUT was equally detrimental to performance for both groups whereas TRI was only associated with errors in the more difficult of two tasks (McVay et al., 2013). In contrast, another study found that TRI was negatively associated with retrieval performance in young adults, but this relationship did not hold true in older adults (Maillet & Rajah, 2013).

In light of the mixed literature, there are several possible interpretations for our results. First, we had high accuracy across tasks (mean accuracies ranged from 0.89 to 0.97), suggesting that our tasks may have been too easy for MW to have a measurable impact on performance. In fact, a previous study found null associations between TRI and performance during simpler as compared to more complex tasks (McVay et al., 2013). However, our Go/No-Go task was akin to the more difficult standard SART used by McVay and colleagues (2013), so similar results would be expected. Second, our tasks were significantly longer (35–60 min) than those used by McVay and colleagues (20 min). This length may have contributed to practice effects in which task-relevant information becomes represented at increasingly abstract levels, decreasing the need for executive control (Anderson, 2013; Smallwood & Schooler, 2006). Further, more attentional resources become available for use, MW rates increase (Giambra, 1995; Smallwood, Baracaia, Lowe, & Obonsawin, 2003). Thus, participants may have shown improvements in performance through automaticity as well as increased MW due to excess availability of cognitive resources, weakening the observed associations. Additionally, variables such as increased fatigue (McVay & Kane, 2009; Smallwood, Riby, Heim, & Davies, 2006; Smallwood et al., 2004) and decreased task engagement (Seli, Cheyne, Xu, Purdon, & Smilek, 2015) are also linked to increases in reported TUT. Third, it is possible that requiring our participants to provide written descriptions of their thoughts increased awareness and resulted in dampened effects of MW on behavioral performance. This is supported by several studies demonstrating that task performance is significantly less disrupted by MW when the participant is aware of its occurrence before being probed than when they are unaware (Smallwood, McSpadden, Luus, & Schooler, 2008; Smallwood, McSpadden, & Schooler, 2007; Smallwood, McSpadden, & Schooler, 2008). Further, there is less recruitment of the executive control network and default mode network when participants are aware of MW (Christoff et al., 2009). In line with these findings, labeling emotional experiences has been found to dampen neural and behavioral responding (e.g., Lieberman et al., 2007). Future studies should pursue a comparisons of the effects of MW when it is unconscious, conscious, and metaconscious (as suggested by Schooler, Mrazek, Baird, & Winkielman, 2015).

Examination of the mediating effect of MW on the relationship between mindfulness and task performance was based on *a priori* hypotheses from Mrazek et al.'s (2013) study in which improvements in reading comprehension and working memory following mindfulness training were mediated by a reduction in TUT. In our study, this model was not significant in the Go/No-Go task or for reactive control. However, we did find that TUT mediated the association between mindfulness and proactive control in the CPT. The indirect effect was driven by a large positive effect of TUT on proactive control use. Interestingly, there was a significant effect of working memory as a moderator of this relationship with a positive effect of TUT on proactive control for those with a low-average WMI score.

One possible interpretation of this finding is that TUT rates indirectly represent the task difficulty at the time of probing. This interpretation is predicated on the assumptions that each individual has a fixed amount of cognitive resources available, that MW competes with task engagement for these resources, and that many tasks do not require one's full resource pool (Thomson, Besner, & Smilek, 2015). Our results indicate that for individuals with low-average working memory there is a positive relationship between TUT and proactive control such that proactive control was poor when TUT rates were low, but proactive control was higher when TUT rates were high (Fig. 2). However, there was no significant relationship between TUT and proactive control for those with high working memory, suggesting that they might possess enough resources to maintain proactive control regardless of task context and MW activity. Notably, the use of proactive control was similar across those with low-average and high WMI when TUT rates were high, possibly representing easier trial types in which all participants were able to effectively employ proactive control while directing excess resources to task-unrelated MW. However, at low TUT those with low-average working memory exhibited poorer proactive control than those with high working memory. Thus, low TUT might represent more difficult trial types in which participants with lower cognitive resources perform poorly and simultaneously must mind-wander less. In line with these interpretations, Mooneyham and Schooler (2013) have reasoned that it is possible to be "mindful" of a task when the task demands it, but to productively mind-wander when the task allows it. Thus, working memory may be an important moderator to examine in future mindfulness training studies as its interaction with MW behavior appears to have important consequences for older adults' cognitive performance.

4.4. Limitations

There are several limitations to the current study that have been considered in the interpretation of the results. First, it is possible that our study was not sufficiently powered to detect some of the effects that were examined. Although this discussion was limited to findings that we can speak about with statistical confidence, there are some effects that were in the expected direction and should not be considered null based on our findings alone. Second, despite the use of a carefully constructed script for instructing participants how to respond to MW probes, it is possible that demand characteristics impacted our data. Participants may have under-reported MW occurrences due to perceived expectations that they should be on task. For these reasons, replication of our findings and continued examinations are necessary.

Additionally, the measurement of abstract constructs such as mindfulness and MW poses challenges for researchers both theoretically and methodologically. There is still no consensus about the most valid approach to studying these constructs, so future research should continue to carefully consider the operationalization of dispositional mindfulness as either unidimensional or multifaceted. Likewise, future research can also benefit from employing multilevel approaches to measuring MW including experience sampling in conjunction with behavioral and biological markers of its occurrence. Finally, the cross-sectional nature of this study is inherently limiting, particularly in the interpretation of the mediation and moderation analyses. We cannot infer causality or directionality due to the lack of temporal order and manipulation of the independent variable (Baron & Kenny, 1986). This is especially pertinent given that there is evidence for bidirectional effects between performance errors and MW (Cheyne et al., 2009), which the current study cannot evaluate directly. However, the models examined in the current study were based on theoretical rationale and findings from previous studies, and the alternative mediation models (i.e., mindfulness mediating the effect of MW on cognitive performance) were not significant. Future studies may extend these findings by examining the effects of mindfulness interventions in older-adult samples as well as by conducting age-group comparisons. Further, the use of neuroimaging to elucidate mechanisms of change would be beneficial to our understanding of the currently understudied relationships between mindfulness, cognition, and the aging brain.

5. Conclusions

Our results provide evidence for an association between dispositional mindfulness and MW in an older-adult sample. Although mindfulness was associated with less frequently reported MW, its associations with behavioral performance were limited. Trait mindfulness was directly related to enhanced reactive control abilities, but not proactive modes of control or Go/No-Go performance. Contrary to findings in the young-adult literature, we did not find an association between MW and performance on either task. However, an examination of the mediating effects of MW revealed that TUT mediated the association between mindfulness and proactive control, with more task-unrelated MW being associated with enhanced proactive control abilities for individuals with low-average, but not high, working memory. These findings point to the unique functioning of MW in older-adult cohorts, which appears to be affected by individual cognitive capacities.

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