Assessing the relationship between trait and state levels of mind wandering during a tracing task

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Abstract

The aim of this study is to investigate whether trait differences in mind wandering can also predict state differences in mind wandering. More specifically, we ask whether dimensions of disengagement, improvisation, and navigation of mind wandering thoughts in daily life also influence these dimensions of mind wandering states during performance of a tracing task. Previous findings concerning the relationship between trait and state mind wandering are inconsistent. Although studies indicate a significant relationship between the two, the correlates of trait mind wandering and state mind wandering are not always the same. Because of this, we expect to shed some light on these inconsistencies by using a novel measure of mind wandering, which captures essential individual differences in the nature of the phenomenon. Our results indicate that individual differences in trait mind wandering significantly predict state differences in content variation of mind wandering and task performance, but not in perceptual decoupling or in mental navigation. Implications of these findings are discussed.

Keywords:

trait mind wandering; state mind wandering; perceptual decoupling; mental improvisation; mental navigation; content variation

Introduction

Previous research has shown that mind wandering is a heterogeneous phenomenon. As such, individuals vary according to the amount they mind wander as well as with regards to the nature and dynamics of their mind wandering thoughts. More specifically, mind wandering experience may vary in terms of degree of disengagement (perceptual decoupling), improvisation (unconstrained thought flow), and navigation across space and time (Goncalves, Dias da Silva, Coelho, & Branco, submitted). Often it involves a navigation from one topic to another, back and forth between the outside external world and internal thoughts and feelings.

Regular oscillations between engagement with the external environment and engagement in internal thoughts are characteristic to our human existence (Smallwood & Schooler, 2015). However, the frequency and degree to which attention decouples from the environment towards internal thoughts and feelings are subject to individual differences (Schooler et al., 2011; Smallwood & Andrews-Hanna, 2013; Schad, Nuthmann, & Engbert, 2012).

In addition to variations in the degree of perceptual decoupling during mind wandering, thoughts frequently focus on events that occur in distinct periods in time, enabling a mental navigation across space and time (Smallwood & Schooler, 2015). Such mental time travel has been associated with regions of the brain associated with episodic retrieval and construction of mental simulations of the past, the future, or alternative realities and fantasies (Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Klinger, 2013).

Finally, next to individual differences in perceptual decoupling and mental navigation, mind wandering varies with regards to its dynamics. The *default variability hypothesis* (Mills, Herrera-Bennett, Faber, & Christoff, 2018) proposes that thoughts ceaselessly move from one topic to the next. Therefore, mental improvisation (i.e. unconstrained flow of thought), which goes hand in hand with content variation of thought, is another important dimension of mind wandering that is prone to individual differences.

Mind wandering as a trait

As a dynamic state, seemingly inherent to human experience, can mind wandering also be described as a trait? Is an individual's stable tendency to mind wander in daily life also reflected in the manner in which the mind wanders during performance of a task? Previous research demonstrates that trait levels of spontaneous and deliberate mind wandering seem to generalize to state levels of spontaneous and deliberate mind wandering (Seli, Risko, & Smilek, 2016). However different correlates have been observed for trait mind wandering and state mind wandering. For example, recent work by Godwin et al. (2017) demonstrates that trait mind wandering is not correlated to working memory capacity, as measured by different span tasks. Meanwhile, Randall, Oswald, and Beier (2014) review a variety of studies that have consistently demonstrated state mind wandering measured both online and post-hoc to be negatively related to working memory. This discrepancy may be related to differences in the manner in which individuals report the content of their mind wandering experiences immediately after experiencing them as opposed to how they reflect about their general mind wandering experiences in daily life. While state mind wandering reflects moment-to-moment experiences, trait mind wandering is more related to a person's character, personality, and identity. Moreover, the degree to which state mind wandering differs from state mind wandering likely differs according to the type of task being performed. For example, although an individual may rate himself as a high trait mind wanderer in daily life, under very engaging tasks, or under tasks in which an individual is proficient at or interested in, they may actually remain highly focused. Therefore, generalizations concerning the relationship between measures of trait mind wandering and state mind wandering must be made with care.

Current Study

Mind wandering has been studied primarily under tasks which are conducive to the experience. These tasks tend to be monotonous and tedious, in order to encourage people to mind wander. With this in mind, we created a variation of the oddball paradigm, in which participants have to trace the path of a ball which bounces diagonally across a screen. Although monotonous, this task requires a certain degree of visual attention towards the external environment for the accurate tracing of the ball and correct detection of targets during a period of approximately one hour.

The goal of the present study is two-fold. First, we expect to replicate previous findings with regards to mind wandering and the oddball paradigm, such that we expect to find more errors and slower response times during states of mind wandering. Second, we investigate whether trait differences in mind wandering can also predict state differences in mind wandering during performance of a task. In particular, we explore whether the degree of disengagement, improvisation, and navigation of mind wandering thoughts both in daily life and during performance of a tracing task. Previous findings concerning the relationship between trait and state mind wandering are inconsistent, such that the correlates of trait mind wandering are not always the same as the correlates of state mind wandering. Because of this, we expect to shed some light on these inconsistencies by using a novel measure of mind wandering[1], which captures essential individual differences in the nature of the phenomenon.

Methods

Participants and Procedure

In total, 45 participants between 18 and 33 years of age (M = 22.53, SD = 3.36[2]), 28 female, performed this experiment and received course credit for their participation. Two participants were excluded because they fell asleep during the study and did not follow the instructions. The study was approved by the university's Institutional Review Board (REDC#2019/98). Before beginning the experiment, participants signed a consent form. Participants then answered questions about their demographics and mind wandering experiences in daily life. Next, they performed the bouncing ball task, in which they were instructed to trace the path of a bouncing ball on a screen as accurately as possible[3]. Sometimes the ball would turn red. Whenever it did, participants were asked to click on it as quickly as possible.

Materials

Mind Wandering Inventory The Mind Wandering Inventory (Cronbach $\alpha = .81$), consisted of 10 items (see Table 1) assessed on a 4-point Likert scale (1 = completely agree to 4 = completely disagree) concerning mind wandering in daily life. The scale was intended to capture trait differences in perceptual decoupling, mental navigation, and mental improvisation. The first 3 items are intended to generally be associated with perceptual decoupling, while the subsequent 3 capture primarily mental navigation, and the final 4 capture primarily mental improvisation and content variation (Goncalves et al., submitted).

Table 1:

Items from the Mind Wandering Inventory
1. My mind often disconnects from what surrounds me
2. While performing a task, my mind is often thinking of other things
3. I am often absorbed with my own thoughts
4. My thoughts travel frequently through time (past or future)
5. I often imagine that I'm somewhere else
6. I often imagine what others are thinking or feeling
7. My thoughts seem to have a life of their own
8. My thoughts jump easily from one subject to another
9. The content of my thoughts is very diverse
10. I spend much of the time daydreaming

Bouncing ball task The bouncing ball task was developed as a variation of the oddball paradigm, a commonly used task for cognitive and attention measurement. Participants were placed approximately 70 centimeters in front of the screen. Stimulus material was presented with a display refresh rate of 60 Hz on a white background. In this study, a black ball "bounced" along a white computer screen. Participants were instructed to trace the path of the bouncing ball and to click on it whenever it turned red. Further, the reaction time and correct target detection for each participant were recorded. Errors were determined as either not clicking within the red ball, or by not clicking at all. 10% of trials were targets and 90% were nontargets. As the task consisted of 5 blocks, each lasting approximately 10 minutes, there were 60 targets and

[1]This measure of mind wandering experiences in daily life was developed by Goncalves et al. (submitted).

[2]$N = 43$. The two participants who fell asleep were not considered in calculating mean values for age or Gender count.

[3]Note that some of the data has been reported in a separate study (manuscript in preparation) and, thus, the current data and that data are not from independent samples. More specifically EEG and mouse tracking data collected during this study are reported elsewhere.

540 nontargets per block (300 targets and 2700 nontargets in total). Total time spent on the oddball task was approximately one hour.

Mind wandering probes Intermittent thought probes assessing participant's state of mind were presented during the bouncing ball task. Mind wandering was calculated as the percentage of thought probes during which participants responded that they were not focused on the task. Whenever participants responded that they were not focused on the task, they were asked to indicate the degree to which their thoughts were disengaged from the task (perceptual decoupling), the degree to which they imagined being somewhere else (mental navigation), and the degree to which the content of their thoughts varies (content variation).

Instrumentation The mind wandering experiences questionnaire was presented online via Qualtrics (Qualtrics, 2005). The bouncing ball task was programmed in E-prime 3.0 (Psychology Software Tools). The experiment was run on full screen mode, with a resolution of 1366 by 768 pixels on a Windows 10 operating system.).

Results

Data were analyzed for 43 participants. Descriptives for the Mind Wandering Inventory, probes, reaction times, and accuracy can be found in Table 2. We determined accuracy as the percentage of trials in which participants correctly clicked on the oddball (target). As probes were presented pseudorandomly during the task, the number of oddballs preceding each probe varied. There were either 2, 4, or 6 oddballs preceding each probe, for a total of 15 probes per block (5 after 2 oddballs, 5 after 4 oddballs, and 5 after 6 oddballs).

In order to determine the accuracy for trials in which participants were focused versus for trials in which participants were mind wandering, we extrapolated answers to the probe to either 2, 4 or 6 trials preceding the probe. We found that irrespective of the amount of trials considered previous to the probe, accuracy was slightly better for trials in which participants were focused ($M = 0.94$, $SD = 0.08$) than in trials in which participants were mind wandering ($M = 0.90$, $SD = 0.12$). Responses to the oddball stimulus were negatively skewed, as the majority of participants responded accurately to the target. Therefore, a paired Wilcoxon's singed-ranks test was performed in order to examine whether the difference in accuracy between the mind wandering and focus conditions was significant. Results indicated that indeed responses during during mind wandering ($Mdn = 0.94$) were significantly less accurate than responses during focus ($Mdn = 0.96$, $Z = 53$, $p < 0.001$). Similarly, reaction times during focused attention ($M = 0.622.47$, $SD = 81.88$) were faster than reaction times during mind wandering($M = 652.36$, $SD = 87.13$). Reaction times during mind wandering and focus trials were normally distributed. Paired t-tests indicated that this difference to be highly significant($t = -6.02$, $df = 42$, $p < 0.001$).

Table 2: Descriptive statistics for Mind wandering Experiences, Mind wandering probes, accuracy, and reaction times.

Measure	Mean	SD
Mind wandering experiences(1-4)	3.40	0.62
Perceptual decoupling (1-4)	3.03	0.61
Mental navigation(1-4)	3.07	0.55
Content variation(1-4)	3.36	0.41
Mind wandering frequency(probes)	0.40	0.19
Perceptual decoupling (1-10)	4.85	2.19
Mental navigation(1-10)	4.52	2.09
Content variation(1-10)	5.49	1.78
% Correct overall	0.92	0.08
% Correct (focused attention)	0.94	0.08
% Correct (mind wandering)	0.90	0.12
RT(correct trials)	634.71	79.61
RT(focused attention)	622.47	81.88
RT(mind wandering)	652.36	87.13

Note: Mind wandering experiences were reported on a Likert scale of 1-4. Mind wandering probes were reported on a scale of 1-10. RT is reported in milliseconds. RTs reported for mind wandering and correct trials only pertain to correct responses (in which participants clicked on the oddball).

Mind wandering across time

When observing mind wandering rates across the task, we found that initially in the first block, mind wandering rates are relatively lower, but as the task proceeds, mind wandering rates increase, remaining steadily higher from the second to the fifth blocks (36%, 46%, 46%, 44%, and 43% for blocks one through 5, respectively).

Trait mind wandering v. state mind wandering

Mind Wandering Inventory In order to explore the factor structure of the Mind Wandering Inventory, we performed a Principal Components Analysis with oblimin rotation. Three components were extracted (eigenvalues < 1) that cumulatively accounted for 26%, 51%, and 64%, of the variance in the answers to the questionnaire (see Table 3.

The first component consists of higher loadings for questionnaire items pertaining to mental navigation (e.g.,"My thoughts travel frequently through time (past or future)"). The second component consists primarily of higher loadings for items related to perceptual decoupling (i.e."My mind often disconnects from what surrounds me") and mental improvisation (e.g.,"My thoughts jump easily from one subject to another"). Lastly, the third component consists of higher loadings for items related to content variation (e.g.,"The content of my thoughts is very diverse").

Interestingly, although content variation is considered to be characteristic of the mental improvisation dimension of the Mind Wandering Inventory, here it seems to load on a new factor (Table 3, represented by high positive loadings for Item

9 (“The content of my thoughts is very diverse”, see Table 1) and high negative loadings for Item 3 (”I am often absorbed with my own thoughts”, see Table 1).

Table 3: Results from the Principal Components Factor Analysis with values for the highest loadings for each component, with ultimate cutoff point of .35.

	1	2	3
Item 1		0.79	
Item 2		0.58	-0.35
Item 3	0.33	0.35	-0.59
Item 4	0.81		
Item 5	0.80		
Item 6	0.76	-0.31	
Item 7		0.57	
Item 8		0.86	
Item 9			0.86
Item 10	0.57		

Correlations In order to investigate the relationship between a general tendency to mind wander in daily life and mind wandering during a task, we first observed correlations between trait and state measures of mind wandering (see Figure 1).Correlations between trait mind wandering experiences and state content variation ($r = 0.42$, $p = 0.007$), trait decoupling and state content variation ($r = 0.32$, $p = 0.038$), as well as between trait navigation and state content variation ($r = 0.32$, $p = 0.038$) were significant.

With regards to state measures, state mental navigation and state content variation were significantly correlated to one another ($r = 0.49$, $p = 0.001$) while state navigation was significantly correlated with state decoupling ($r = 0.31$, $p = 0.041$). However, state decoupling and content variation were not significantly correlated to one another.

Interestingly, reaction times during mind wandering were significantly negatively correlated to probe responses for perceptual decoupling ($r = -0.35$, $p = 0.021$), indicating that shorter reaction times were associated with a higher degree of perceptual decoupling. In addition, accuracy during mind wandering trials was also significantly negatively correlated to the reaction times during mind wandering trials ($r = -0.60$, $p < 0.001$), such that higher accuracy in oddball trials during which participants reported to be mind wandering was associated to quicker reaction times. Moreover, accuracy was also significantly associated to trait content variation ($r = 0.31$, $p = 0.043$), such that higher accuracy during mind wandering trials was associated to greater content variation of mind wandering thoughts.

In order to investigate whether trait levels of mind wandering predict differences in state content variation of mind wandering, we performed a linear regression. As input for the regression, we included responses to the Mind Wandering Inventory, seeing that correlations between state content variation and the entire questionnaire were stronger than correlations with individual components of the MWI. Results of the regression indicate that state content variation in mind wandering was significantly predicted by trait mind wandering experiences ($R = 0.4$, adjusted-$R^2 = 0.15$, $F(1,41) = 8.15$, $p = .007$). Regression coefficients are shown in Table 4.

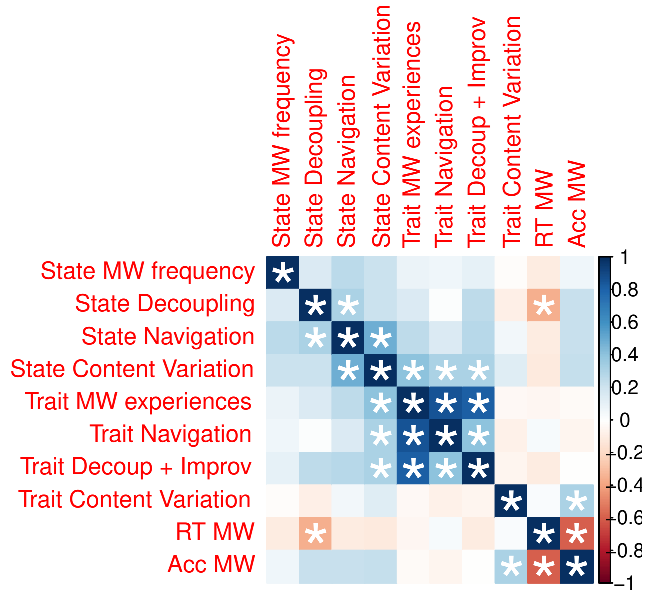

Figure 1: Correlations between trait mind wandering, state mind wandering, reaction time and accuracy during the oddball task. Here, reaction time and accuracy are only reported for trials in which participants reported mind wandering.

Table 4: Responses to the MWI as a predictor of state content variation in mind wandering.

	B	*SE(B)*	*t*	*p*
(Intercept)	-0.53	1.76	0.30	.77
Trait content variation	1.59	0.56	2.86	.007

Adjusted $R^2 = 0.15$, $p = .007$

Discussion

In line with previous literature (Smallwood & Schooler, 2015; Seli, Cheyne, & Smilek, 2013), we found mind wandering rates between 20 and 50% during the bouncing ball task. Despite the high accuracy rates in the oddball task, we did find differences in accuracy and reaction times in conditions during which participants were mind wandering. As expected, longer reaction times were associated with decreased accuracy. Moreover, accuracy was significantly higher during trials in which participants were focused than when they were mind wandering.

We also found that the nature of thoughts influenced the extent to which reaction times were affected. Interestingly, and somewhat counter-intuitively, shorter reaction times were particularly associated with a greater degree of perceptual decoupling. Although, in general, reaction times were slower during mind wandering than during focused trials, when observing the trials in which participants were mind wandering, greater levels of disengagement (perceptual decoupling) were associated with quicker response times. This increase in speed may be a result of an increase in automatic movements (Morsella, Larson, & Bargh, 2010).

When exploring the factor structure of the Mind Wandering Inventory, we found that three factors emerged that together account for 1) mental navigation, 2) perceptual decoupling together with mental imropovisation, and 3) content variation of mind wandering thoughts. Although content variation is considered to be an index of the mental improvisation dimension of the Mind Wandering Inventory, here it seems to load on a new factor pertaining to the variation of thought versus the quality of being absorbed in one's thought. The factor loading for the item pertaining to content variation is positive, while the loading for the item pertaining to absorption in thought is negative. As such, content variation is inversely related to absorption, such that higher degrees of content variation likely correspond with lower degrees of of absorption.

The quality of being absorbed in thought seems to be akin to what van Vugt and Broers (2016) denote as "stickiness", reflecting the difficultly to disengage from thought. Interestingly, these authors (van Vugt & Broers, 2016) found that increased stickiness of thoughts was associated with longer response times during a Sustained Attention to Response Task. Relatedly, the content variation factor that emerged from the Mind Wandering Inventory also seems to affect task performance, such that more content variation and less absorption in thoughts is related to increased accuracy during trials in which participants reported mind wandering. It may be that this component is reflective of an adaptive ability to mind wander whenever the situation allows for it. In the context of this task, such an ability is likely useful for coping with boredom without hurting performance on the task.

With respect to state measures of mind wandering, we found that mental navigation and content variation were strongly correlated to one other. As such, whenever participants reported higher degrees of mental navigation (i.e.,"I imagined being somewhere else"), they also reported higher degrees of content variation (i.e., "The contents of my thought varied"). Moreover, mental navigation was moderately related to perceptual decoupling (i.e., "My attention was disengaged from my surroundings"). However, perceptual decoupling was not significantly correlated to content variation. As such, any change in the degree of content variation was independent of any change in the degree of perceptual decoupling.

Lastly, we found that a tendency to mind wander in daily life does not predict the frequency of mind wandering on a task. Nor does it necessarily predict the nature of the experience during task performance.The Mind Wandering Inventory tapped into general patterns of thought likely inherent to a person's character and personality, while the mind wandering probes tapped more into moment-to-moment states of thought.

Importantly, however, we did find a significant relationship between answers to the Mind Wandering Inventory and content variation of thoughts during performance of the task. However, trait levels of mind wandering did not predict either perceptual decoupling nor mental navigation. As such, individual trait differences in mind wandering thoughts as captured by the Mind Wandering Inventory along with the first two emergent factors (which capture variance in mental navigation, perceptual decoupling, and mental improvisation) generalize to state level changes in content variation of mind wandering thoughts. In contrast, trait differences in content variation (and absorption) do not generalize to any changes in state dimensions of mind wandering, but are related to changes in accuracy during the task.

Taken together, our results indicate that individual differences in the tendency to mind wander in daily life seem to generalize to state level variations in mind wandering content as well as accuracy during this task. In contrast, though, trait levels of mind wandering do not predict differences in state decoupling and mental navigation in this task.

Conclusion

The relationship between trait mind wandering and state mind wandering is not a straightforward one. It seems to depend considerably on the nature of the inner experience being assessed. From our findings, responses to the Mind Wandering Inventory is able to predict content variation of thoughts during a monotonous task. However, why this relationship holds for this dimension of mind wandering and not for others is still an open question. Further investigation of different measures of mind wandering at both trait and state levels under different tasks is needed for a better understanding of the relationship between mind wandering as an inherent aspect of our personalities and as a state that ebbs and flows during the course of our daily lives.

Supplementary Information

All materials used in the task are available upon request.

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