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Is an off-task mind a freely-moving mind? Examining the relationship between different dimensions of thought

Caitlin Mills[a,*], Quentin Raffaelli[a], Zachary C. Irving[c], Dylan Stan[a], Kalina Christoff[a,b]

[a] Department of Psychology, University of British Columbia, Canada
[b] Centre for Brain Health, University of British Columbia, Canada
[c] Department of Philosophy, University of California, Berkeley, USA

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ABSTRACT

Mind wandering is frequently defined as task-unrelated or perceptually decoupled thought. However, these definitions may not capture the dynamic features of a wandering mind, such as its tendency to 'move freely'. Here we test the relationship between three theoretically dissociable dimensions of thought: freedom of movement in thought, task-relatedness, and perceptual decoupling (i.e., lack of awareness of surroundings). Using everyday life experience sampling, thought probes were randomly delivered to participants' phones for ten days. Results revealed weak intra-individual correlations between freedom of movement in thought and task-unrelatedness, as well as perceptual decoupling. Within our dataset, over 40% of thoughts would have been misclassified under the assumption that off-task thought is inherently freely moving. Overall, freedom of movement appears to be an independent dimension of thought that is not captured by the two most common measures of mind wandering. Future work focusing on the dynamics of thought may be crucial for improving our understanding of the wandering mind.

1. Introduction

The last decade has seen an explosion of scientific research on mind wandering, leading some researchers to dub the 21st century 'the era of the wandering mind' (Callard, Smallwood, Golchert, & Margulies, 2013). The number of scientific publications with the term 'mind wandering' in the title has increased from only one in 2006 to over 50 in 2016, making mind wandering a prominent topic in cognitive (Andrews-Hanna et al., 2013; Schooler et al., 2011) and clinical psychology (Fox, Kang, Lifshitz, & Christoff, 2016; Marchetti, Koster, Klinger, & Alloy, 2016; Murphy, Macpherson, Jeyabalasingham, Manly, & Dunn, 2013; Stan & Christoff, in press-a), as well as education (Mills, D'Mello, & Kopp, 2015; Schooler, Reichle, & Halpern, 2004; Wammes, Boucher, Seli, Cheyne, & Smilek, 2016) and neuroscience (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Esterman, Noonan, Rosenberg, & DeGutis, 2012).

This burgeoning of scientific publications, however, has occurred in the midst of uncertainty about what it means for a mind to wander. Most research to date has used the term 'mind wandering' to loosely refer to either one of two dimensions of thought: (1) task unrelated thought (i.e., off-task; Smallwood & Schooler, 2015) or (2) stimulus independent thought, which is "perceptually decoupled" from one's surroundings (Schooler et al., 2011). For example, we examined the 55 peer-reviewed articles with 'mind wandering' in the title published in 2016 and listed on PsychInfo or Google Scholar. We found that 52 of these articles (94.5%) used the term 'mind wandering' to refer to off-task thought; 30 of the same articles (54.5%) used 'mind wandering' to refer to a state of perceptual decoupling.

* Corresponding author at: 2136 West Mall, University of British Columbia, Vancouver, BC V6T 1Z4, Canada.
E-mail addresses: caitlin.s.mills@psych.ubc.ca (C. Mills), quentinraffaelli@psych.ubc.ca (Q. Raffaelli), zac.irving@gmail.com (Z.C. Irving), dylanstan@gmail.com (D. Stan), kchristoff@psych.ubc.ca (K. Christoff).

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Table 1
Task-relatedness is empirically dissociable from freedom of movement in thought. (A) If off-task thought and freely-moving thought are not empirically separable and off-task thought co-occurs systematically with freely-moving thought, then the following pattern of results should be expected: the vast majority or almost all responses should fall in the *off-task + freely* moving and *on-task + constrained* thought cells (based on previous literature, up to 50% of thoughts should be *off-task* and the remaining should be on-task); at the same time, very few or no responses should fall in the *off-task + constrained* and *on-task + freely-moving* cells. (B) Observed pattern of data in the current study. Each cell represents average proportion of responses in each cell across participants. Individual probe responses were z-score standardized within participant, then split based on each participant's individual median; 1.2% of data fell on the median and was not included. Less than 60% of the data fell into cells that account for *off-task + freely-moving* thoughts and *on-task + constrained* thoughts. More than 40% of the data fell into cells describing *off-task + constrained* and *on-task + freely-moving* thoughts – two categories of thought that should occur rarely or not at all, if being off-task was not empirically dissociable from having a wandering mind.

(A) Hypothesized pattern if dimensions are not independent			(B) Observed results		
	Freely-moving	Constrained		Freely-moving	Constrained
Off-task	~50%	~0%	Off-task	28.9%	20.2%
On-task	~0%	~50%	On-task	21.8%	27.9%

A recent theoretical account (Christoff et al., 2016) highlights a different view of mind wandering, which emphasizes its dynamics, or how mental states arise and unfold over time. In this view, a wandering mind tends to move relatively freely across multiple possible mental states. Thoughts move in an unconstrained manner from one to the next: the last time you spoke to your best friend, a memory with your friend years ago, plans with a different friend for dinner, to your favorite dishes at a restaurant. The content of thoughts may end up being thematically or episodically linked to some extent over time (Mills, Herrera-Bennett, Faber, & Christoff, in press), but a key feature is that they arise relatively freely with little deliberate (e.g., goal-oriented) or automatic (e.g., habitual, affective cues) constraints.

Although Christoff et al. (2016) highlight the theoretical importance of freedom of movement in thought, the dominant dimensions in the literature (i.e. off-task and stimulus independent thought) do not explicitly capture constraints on thought as part of their definitive qualities. This may not be an issue if off-task thought is inherently freely moving, but currently we do not know the extent to which they are related. If being off-task is synonymous with having a freely-moving mind, task-unrelated thought should have a freely-moving quality to it (Table 1A). Our thoughts would then be expected to fall predominantly within two categories: they should be either *off-task and freely-moving* or *on-task and constrained* (Table 1A). Thoughts that fall within the other two categories (either *off-task and constrained* or *on-task and freely-moving*) should occur rarely or not at all. In this case, the correlation between being off-task and having a freely moving mind should be strong, and the characterization of off-task thought could simply be elaborated to include the tendency for the mind to be freely moving.

In principle, however, task-relatedness and free movement of thought are two conceptually dissociable dimensions. Off-task thoughts may not be inherently freely-moving: off-task thoughts might become constrained and focused, such as when one is worrying about an upcoming presentation or a prior mistake. If this is true, the four categories of thought depicted in Table 1 may occur with similar frequency in everyday life, demonstrating that task-relatedness and freedom of movement in thought are empirically dissociable. This latter possibility would be inconsistent with a theoretical view that equates being off-task with having unconstrained, freely moving thoughts. Thus, in the current work we focused on evaluating whether freely-moving thought can be distinguished from off-task thought, the predominant definition of mind wandering. This approach adds to a growing body of work that has refined our understanding of mind wandering by seeking to identify its key, distinguishable dimensions (Seli, Risko, & Smilek, 2016; Seli, Risko, Smilek, & Schacter, 2016).

We tested whether the free movement of thought is empirically dissociable from task-relatedness by using experience sampling of participants' thoughts in everyday life. Experience sampling during daily life is a commonly used method to assess task-unrelated thought (Kane et al., 2007; Killingsworth & Gilbert, 2010; Song & Wang, 2012). We also tested whether free movement of thought is empirically dissociable from perceptual decoupling – the second most frequently assumed feature of a wandering mind. Each thought probe was delivered on participants' mobile phones, and asked participants to report on the extent to which their thoughts (i) were moving about freely, (ii) were about something other than what they were currently doing, and (iii) contained awareness of their surroundings. By measuring variations in these three dimensions of thought concurrently, we aimed to provide empirical evidence for a novel dimension of thought: one that is not based on the content of the thought, but how freely the mind is moving.

2. Methods

A total of 228 participants enrolled at a large public Canadian university took part for class credit. A sample size of about 200 (at least 194) was needed based on a power analysis in which we estimated a correlation of 0.2 ($\alpha = 0.05$, and $\beta = 0.2$) was estimated for inter-individual correlations.

After signing up, participants came to the lab for a thirty-minute training session in order learn about the study. Upon arrival, they were asked to complete an informed consent. Participants were then given a brief (~20 min) training session. The session included detailed verbal instructions given via video recorded power-point. The video detailed definitions and examples of each dimension, and the video was paused periodically for participants to engage in discussions about each dimension, including being asked to give novel examples and the opportunity to answer any clarification questions to the experimenter. Portions of the exact script used in the video are included in Appendix A. Participants were asked to respond to as many of the probes as possible by keeping their phone near them when it was feasible.

2.1. Materials and procedure

Participants were probed to answer probes 10 times per day for 10 days (100 total) via URL links sent directly to their mobile phones. Each probe included a total of seven questions (Appendix B).[1] Here we focus on three questions pertinent to the definition of mind wandering, which were answered on a scale from (1) *Not at all* to (7) *Very much*:

(1) Was your mind moving about freely?
(2) Were you thinking about something other than what you were doing?
(3) Were you aware of your surroundings?

A total of 15,286 responses were collected (M = 68.2 responses per participant; SD = 19.0). We analyzed data from participants who responded to at least 60% of the probes in order to have enough data to compute intra-individual correlations (N = 165; M = 77.5; SD = 9.68). However, we note that the pattern of results is unchanged if every participant's data is used.

2.2. Initial validation of the freely moving question

Two of our three central questions (i.e. *were you thinking about something other than what you were doing*, and *were you aware of your surroundings*) have been used extensively in previous experience sampling studies of mind wandering (Kane et al., 2007; Killingsworth & Gilbert, 2010; Poerio, Totterdell, & Miles, 2013; Song & Wang, 2012). However, no published studies to date have employed the question assessing free movement of thought. Despite the historical critiques of introspective reports on mental states (Nisbett & Wilson, 1977; for a counter-argument see Smith & Miller, 1978), more recent work suggests that reports about inner experiences (achieved by experience sampling procedures) are reliably corroborated by distinctive patterns of brain activity, giving merit to the validity of introspective reports (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Hurlburt, Alderson-Day, Fernyhough, & Kühn, 2017). However, given the novelty of the question regarding freedom of movement, a valid concern is that it may not correlate with any other measures simply because of low validity.

To establish initial convergent validity for our measure of freely moving thought, we correlated participants' own ratings of free movement in thought with a blind rater's subjective rating of free movement, as assessed by participants self-reported thoughts. For this comparison, a separate set of participants (N = 23) completed a 30-min *stream of consciousness sampling task* in the laboratory. In this task, participants were told to "think about whatever you want" for an interval of time between 1.5 and 4 minutes (duration was pseudorandomized across participants). Immediately following the thinking period, participants rated how freely moving their thoughts were during the interval using the same question employed in the current research ("Was your mind moving about freely?"). Immediately following the rating, participants typed out their thoughts during the thought interval in chronological order, beginning with the start of the interval. Participants completed this *thinking-rating-typing* cycle two to four times consecutively. We analyzed thought intervals where participants typed at least five thoughts (N intervals = 44 from 18 subjects).

A blind rater coded each interval of thoughts based on a subjective assessment of the extent to which thoughts were freely moving according to the typed content. This assessment was based on the extent to which thoughts appeared to be unconstrained or lacking clear direction on a scale of 0 (totally constrained thoughts; evidence of constraints throughout the interval of thoughts) to 5 (completely unconstrained; no evidence of deliberate or automatic constraints in the interval of thoughts). To the extent possible, the coder applied the instructions provided to participants (see Appendix A) as a guide for rating (i.e. there is no overarching purpose or direction to your thinking, although there may still be some connection between one thought and the next). As an example, the following is an anonymized participant's thought report for a single thought interval rated as unconstrained (5) on the scale: "thinking about my jean jacket/ I want a real army jacket/ I really do not like the army/ but I see a use in it/ although technically there would be no use for the army if every country did not have an army/ like Costa Rica/ I really want to go with XXX to Costa Rica/ I want to go party with her/ She's literally the nicest person in the world/ Or instead of Costa Rica I can go to Brazil." In contrast the following is an anonymized thought report for an interval rated as highly constrained (0) on the scale: "I wish I could not think about XXX's illness/ I can't get it out of my mind/I hate it that she has to deal with all this/ I wish I lived closer to help her/I don't know what to do."

The rater was blind to participants' rating of free movement, perspective, history and circumstance; the rater was only informed by the participant's thought content. If both the blind rater's and the participant's rating reflect the dimension of unconstrained (free) vs. constrained movement in thought, the ratings should be positively correlated. Such a correlation would provide initial convergent validity to the question "Was your mind moving about freely" as a measure of freedom of movement in thought.

We assessed the relationship between the blind rater and participants' ratings by computing a linear mixed effects linear regression using the lme4 package in R (Bates et al., 2016). Models were estimated using restricted maximum likelihood estimation (REML) with an unstructured covariance structure. Two random effects were included: a random intercept for each subject to account for baseline within-subject variability, and a random slope for each subject, such that differences in the relationship can vary across participants. An additional fixed effect was included to control for the number of thoughts reported in an interval. We used the 'LMERConvenienceFunctions' package in R (Tremblay & Ransijn, 2013) to estimate p-values for the analysis of variance corresponding to each model term. We report the conservative p-value estimate (i.e. lower bound) where the denominator degrees of

[1] Participants were also asked to fill out a personality questionnaire via email a week after data collection was complete. However, since only approximately half of the participants responded to this request, we did not analyze those data.

freedom (*df*) were calculated as the total number of observations minus the number of fixed effects and the total number of random effects (e.g., 44 observations − 3 fixed + 36 random effects = 5 remaining *df*).

The regression suggested that participants' ratings of free movement were positively related to the blind rater's assessment of free movement, $F(1,5) = 6.97$, $p = .046$, β (standardized regression coefficient) = 0.431. Additionally, the sheer number of thoughts in an interval was not related to participants' rating of how freely-moving their thoughts were, $F(1,5) = 1.05$, $p = .364$, β = 0.175. A similar regression was used to assess the relationship between participants' freedom of movement rating and the proportion of task-unrelated thoughts in a given interval (count of thoughts about the task itself/total thoughts in thought interval). Although the regression was non-significant, $F(1,5) = 3.53$, $p = .119$, β = 0.266, we do not place much weight on this finding given the internal nature of the task, and the high number of thoughts considered task-unrelated ($M = 81\%$, $SD = 18\%$).

Although we have established some convergent validity with an independent rater's coding, another validity concern is that the question about freedom of movement in thought may not meaningfully relate to other measures. Thus, we turn to another dataset to assess if freely-moving thoughts correlates with valence, a dimension of affect that has been a 'hot topic' in field of mind wandering for the last decade (Franklin et al., 2013; Killingsworth & Gilbert, 2010; Marchetti et al., 2016; Poerio et al., 2013; Smallwood, Fitzgerald, Miles, & Phillips, 2009).

The dataset ($N = 57$) used a similar stream of consciousness sampling task that was adapted for use on Amazon's Mechanical Turk (AMT), which has been shown to produce valid and reliable data (Buhrmester, Kwang, & Gosling, 2011; Rand, 2012; Sprouse, 2011). In this task, participants rated their valence (very negative to very positive feelings) on a 1–9-point scale in addition to rating how freely moving their thoughts were. There was a total of 105 thought intervals with at least five thoughts. A linear mixed effects regression (with a random slope and random intercept) revealed that valence shared a significant positive relationship with freely-moving thought even after controlling for the total number of thoughts produced, $F(1,16) = 21.0$, $p < .001$, β = 0.515. This tentative positive relationship is in line with recent theoretical accounts of freely-moving thought, which suggests that negative affect places 'automatic constraints' on thought, whereas the absence of such constraints promotes more free movement in thought (Christoff et al., 2016).

In sum, the evidence provided here demonstrates the initial validity of our measure of free movement of thought in the context of the laboratory and AMT: the question is positively related to subjective ratings of freely-moving thought, as well as another meaningful dimension of affect, valence.

3. Results

3.1. Off-task thought as mind wandering

First, we evaluated the strength of the relationship between task-relatedness and freedom of movement using intra-individual correlations (see Fig. 1). We computed the correlation between freedom of movement and task-relatedness within each participant. If off-task thought is the same as freely moving thought, we would expect to see strong positive correlations between the two variables. Instead, being off-task was positively but weakly related to having freely-moving thoughts: the average correlation across all participants was 0.242 ($SD = 0.221$; 95% CI of *M*: 0.207, 0.274), consistent with a small effect size (0.1 is small and 0.3 is a medium effect for correlations; Cohen, 1992).

For completeness, we also assessed the same relationship by computing a mixed-effects linear regression using the 'lme4' package (Bates et al., 2016). Similarly to the validation regressions, models were estimated using REML with an unstructured covariance structure and *p*-values were conservatively estimated using the 'lower bound' degrees of freedom provided by the 'LMERConvenienceFunctions' package. All variables were z-score standardized using the grand mean (between participant). Freedom of movement ratings were regressed on task-unrelatedness ratings. The model included a random intercept to account for baseline variability across participants and a random slope, which allows for the relationship itself to vary across participants. Including both a random intercept and slope is appropriate in this case since we cannot make any prior assumptions about the inter-individual variability of the relationship between free movement and task-relatedness. Previous researchers also urge the use of random slopes in order to reduce both Type I and II errors (Barr, Levy, Scheepers, & Tily, 2013; Schielzeth & Forstmeier, 2009).

Task-unrelatedness was significantly related to freely moving thought, which is not surprising given the sample size is large enough to detect a small effect, $F(1,12273) = 176$, $p < .001$, β (standardized regression coefficient) = 0.247, $SE = 0.019$. Importantly, task-unrelatedness accounted for less than 7% of the variance in freely moving thought, whereas the random effect (i.e. participant) explained 18.3% (using the R^2 approach for mixed effects models described by Nakagawa & Schielzeth, 2013).

Second, we assessed the correlation between freely-moving thought and task-unrelatedness across participants (i.e. the inter-individual correlation). While the intra-individual correlations assessed the correlation at the level of thought-reports, the inter-individual correlation allows us to examine the relationship at the person level. That is, are participants who generally report their thoughts as being more freely moving more likely to report being off-task as well? The inter-individual correlations were computed using each individual's average rating across all thought-reports on the task-unrelatedness and freedom of movement scales. Participant's average ratings of task-unrelatedness were weakly correlated with their average rating of freely-moving thought, $r(165) = 0.156$, $p = 0.046$ (see Appendix C for scatter plot).

Finally, we assessed how participants' data would have been categorized using the most common way of defining mind wandering. As an example, task-unrelated thought is sometimes assessed using a continuous response variable (e.g., similar to the one used here), yet can be converted into a binary variable for analyses (task-related versus task-unrelated; Mrazek et al., 2012). We used a median split approach to compute the average percentage of thoughts that fell in each of the four categories described in the

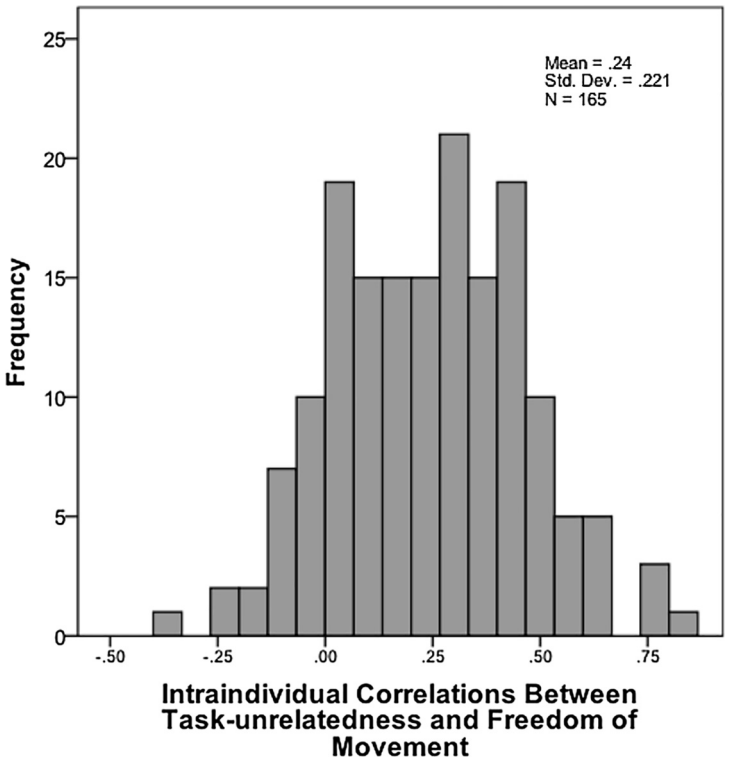

Fig. 1. Histogram representing the intra-individual correlations between task-unrelatedness and freedom of movement.

introduction[2] (Table 1). Here, probe-level responses were z-score standardized within participant to account for potential baseline levels of differences across participants. Then, each participant's median values were used as split points for freedom of thought and task-relatedness, respectively. Each thought-response was classified as being 'high' or 'low' on both dimensions. High values corresponded to either task-unrelated or freely-moving thoughts, whereas low values corresponded to either task-related and constrained thought. Together, the two dimensions combined to make up the four categories and we computed participants' average percentage of thoughts that fell in each (1.2% of data fell on the median and were not included; see Appendix D for full statistics). The four categories are shown in Table 1B.

On average, thoughts were *both off-task and freely-moving* 28.9% of the time (SD = 14.4%). A similar proportion of thoughts were both *on-task and constrained* (M = 27.9%; SD = 14.0%). The proportion of thoughts that were *on-task and freely-moving* (M = 21.8%; SD = 13.8%), or that were *off-task and constrained* (M = 20.2%; SD = 14.6%), was somewhat lower. However, jointly the latter two categories made up for more than 40% of thoughts. These two latter cells were also significantly different from zero (on-task/freely-moving: $t(164) = 20.3$, $p < 0.01$; off-task/constrained: $t(164) = 17.7$, $p < 0.01$).

Taken together, results argue against equating being off-task with having thoughts that move about freely. Although there is a weak relationship between these two dimensions, equating them would mean misclassifying (or neglecting) more than 40% of thoughts.

3.2. Perceptual decoupling as mind wandering

Perceptual decoupling (i.e. awareness of surroundings) was also weakly correlated with freedom of thought, consistent with a small effect: the average intra-individual correlation was 0.105 (SD = 0.186; 95% CI: 0.024, 0.088) and the inter-individual correlation was 0.107, p = .173 (intra-individual correlation histogram in Fig. 2; scatter plot of inter-individual correlation in Appendix D). As described above, we also computed a mixed-effects linear regression to assess the relationship between freedom of thought and awareness of surroundings (Bates et al., 2016). Again, ratings of freedom of movement were regressed on ratings of awareness of surroundings; random effects were the intercept and slope. Awareness of surroundings accounted for 1% of the variance in freely moving thought, $F(1,12273) = 42.4$, $p < 0.001$, $\beta = 0.105$, $SE = 0.016$. The random effect (i.e. participant) explained 17.2%, consistent with a higher proportion of variance explained by participant in the task-unrelatedness regression as well (Nakagawa & Schielzeth, 2013). Taken together, these results once again against equating perceptual decoupling and a freely moving mind.

[2] Analyses were completed with both z-score standardized and raw data (see Appendix F for raw data). Both yielded similar pattern of results (i.e. all four cells were signficantly different from zero). We focus on z-score standardized data because raw data analyses required the exclusion of approximately 37% of the data that fell on the median.

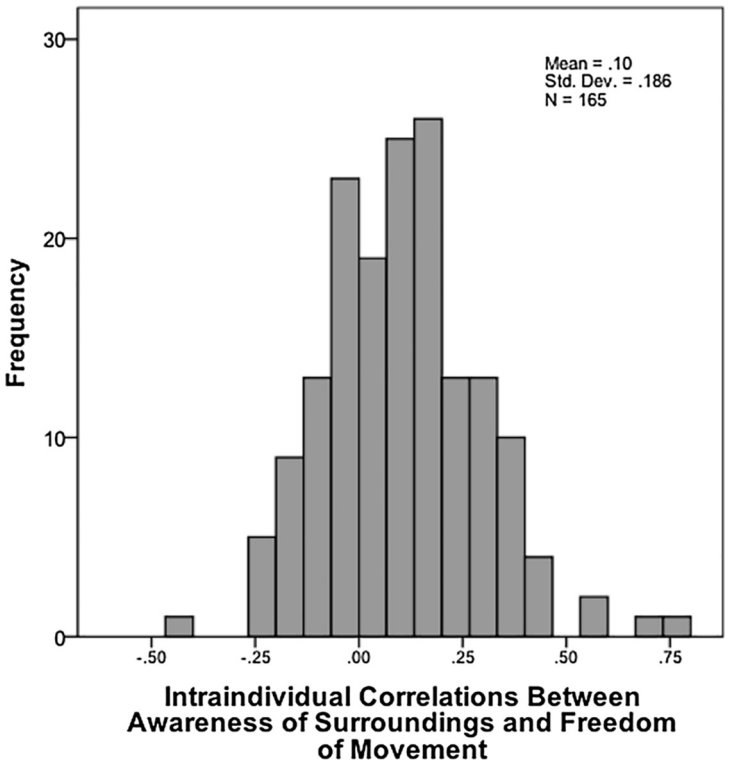

Fig. 2. Histogram representing the intra-individual correlations between awareness of surroundings and freedom of movement.

A similar median split analysis was used to examine the relationship between perceptual decoupling and a freely-moving mind (Table 2). Participants reported having freely-moving thought while being perceptually coupled with their surroundings an average of 26.1% of the time (SD = 14.5%), which was comparable to the frequency they reported constrained and perceptually coupled thought (M = 23.0%; SD = 16.9%). Similarly, participants experienced constrained thought while being perceptually decoupled an average of 24.6% of the time (SD = 13.3%), while freely-moving and perceptually decoupled thought occurred an average of 24.2% of the time (SD = 14.5%). Once again, over 50% of the data would have been a priori neglected under the assumption that perceptually decoupled thought is equivalent to a freely moving mind.

4. Discussion and conclusion

The present results demonstrate that freely-moving thought is empirically dissociable from task-relatedness (being off-task) and stimulus-independence (being perceptually decoupled). Freely-moving thought showed only weak relationships (consistent with small effect sizes) with these two commonly studied dimensions of thought in the content of mind wandering research in an everyday life setting. These results suggest that the degree of freedom of movement in thought is an independent dimension of thought that captures information regarding a person's mental experience that cannot be fully predicted based on measures of task-relatedness and stimulus-independence.

An overwhelming number of studies use off-task thought to assess mind wandering. Thus, most of what we know about how mind wandering relates to other important variables (e.g., affect, clinical symptomology, creativity, educationally relevant outcomes, boredom) are based on off-task thought alone (Baird et al., 2012; Killingsworth & Gilbert, 2010; Mills, Graesser, Risko, & D'Mello, 2017; Phillips, Mills, D'Mello, & Risko, 2016; Poerio et al., 2013; Raffaelli, Mills, & Christoff, 2017; Smallwood, 2011; Smallwood et al., 2009). Real-time detectors of thought patterns using machine learning have also been limited to predicting off-task thought (Faber, Bixler, & D'Mello, 2017; Hutt, Mills, White, Donnelly, & D'Mello, 2016; Mills, Bixler, Wang, & D'Mello, 2016; Mills & D'Mello, 2015).

Table 2
Average percentage of thoughts that fall in each category. Perceptual awareness is conceptually dissociable from freedom of movement in thought (0.2% of thought reports fell on the median and is not included).

	Freely-moving	Constrained
Unaware	24.2%	24.6%
Aware	26.1%	23.0%

There is an important open question as to how freely-moving thought will relate to these variables, all of which are ecologically relevant. To this end, we suggest that future work should focus on uncovering potential dissociable relationships between the three dimensions outlined here. Future work can also help hone our understanding of mind wandering by focusing on additional and largely unstudied dimensions of thought and their differential relationship to the dynamics of mental states (Kucyi, Esterman, Riley, & Valera, 2016; Seli et al., 2016; Stan & Christoff, in press-b). Measuring freedom of movement in thought may be particular crucial for capture the dynamics of thought (Ellamil et al., 2016; Girn et al., 2017) that have recently become a focus of exploration within cognitive neuroscience along with the introduction of dynamic functional connectivity measures (Dixon et al., 2017; Kucyi, 2017)

The research described here has a number of limitations that should be noted. First, we used a new measure to asses freely moving thought – a single question that requires introspection. We provided precise instructions for the question during a training session, yet we acknowledge that there is still room for individual variability in the interpretation of this question, a limitation that is inherent to the experience sampling methodology. Although we provide initial evidence of validity for this question in our Methods section, more work needs to be done to fully establish this question's psychometric validity. Second, although experience sampling in everyday life offers important ecological validity, it is accompanied by some drawbacks. For example, we had no control over how quickly participants responded and we did not know what they were doing at the time of responding. Nevertheless, everyday life experience sampling has been an important tool in the field of mind wandering, and our results very closely match other studies using this methodology: for example, Killingsworth and Gilbert (2010) reported people being off-task 46.9% of the time, and the rate in our study was 49.1% (from data presented in Table 1). Third, we only compared freely-moving thought to the two most common ways mind wandering is studied in the literature (off-task and stimulus-independent). Future work may address how freely-moving thought compares to other dimensions, such as stimulus independent + task-unrelated thoughts and intentional/unintentional off-task thought. Despite these limitations, the present results strongly suggest that a freely moving mind is an independent dimension of thought that requires at least as much consideration as task-relatedness and stimulus-independence when it comes to understanding the phenomenon of mind wandering. Considering this novel dimension in future work will contribute to a richer understanding of what it means for a mind to be wandering and how this ubiquitous mental phenomenon relates to other aspects of everyday experience.

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Appendix A. Instructions

Notes: Every participant was trained in a small group people. The same experimenter was in the room for the entire question and answer question. The same training video was shown to all participants.

A.1. Introducing study and explaining how the probes work

Verbal instructions given via video: So, in this short video, we're going to tell you everything you need to know. There's a lot of information, so pay close attention. But we're going to pause throughout to make sure that you're grasping it correctly and we're going to answer any questions. Keep those in mind. And here we go.

The basics is that we're going to get you to rate your mental activity in a survey that you're going to be answering a number of times throughout the day. You're going to get text messages at random times with a web link in them, and you're going to click that, and you're going to go to the survey, and it's really important that you answer right away when you get the text. Actually, you have to answer within 10 s. If you're driving, or if you're in a situation during which you absolutely can't answer right then and there, you should just not answer at all. Don't set it aside and try to answer later because we can see that. That being said, try to interrupt whatever you're doing. It's really important that you answer as many of these as possible.

Now, as soon as you hear the beep, you're going to click on the link and go to the survey. And we're going to get you to save the number into your phone and customize the text message tone. We'll give you instructions later on how to do that. But it's very important that these text messages stand out from any other text messages for reasons we're about to tell you. You need to know right away, when you hear the tone, that it is one of these important text messages. So, when you're answering the survey, we want you to finish within 40 s. Now, I mean, that may seem like a short amount of time, but once you've practiced a couple of times actually it's going to get very fast. You'll probably be able to do it within 30 s. So answering quickly and intuitively is important as well. And it's also very important that you keep your phone around you. Obviously, if you're going to be answering quickly, and you need to answer a lot of these, keep your phone on, keep the sound up loud, and keep it within arms reach at all times as much as possible. And finally, you need to answer at least 80% of these probes.

So this is a survey about your thought activity. What do we mean by thoughts? By thoughts, we mean anything that is going on in your awareness. That can include internal stuff like memories, emotions, imagining things. It can also mean external things. So if you're aware of sensations in your body, or things that you see or hear or smell. You get the picture.

So when you hear that special tone on your phone, you're going to take a mental snapshot of what's going on in your awareness at the time. So you hear the tone, you pause briefly, your take a snapshot, and then you're going to open the text, click the link, and you're going to go and answer all the questions keeping that mental snapshot in mind.

A.2. Explanation of free movement

Was your mind moving about freely?
Your thoughts move freely when:

- They seem to wander around, flowing from one thing to another
- There is no overarching purpose or direction to your thinking. Although there may still be some connection between one thought and the next
- Images and memories seem to spontaneously come into your mind
- Your attention lands spontaneously on things in your environment
- Your mind may spontaneously drift between things in the external environment and internal images so it may go back and forth.
- Your thoughts move freely when it feels like your thoughts could land on pretty much anything
- Or that your thoughts seem to flow with ease

For example, you know, you're on the bus going home. you might take the following snapshot of your thoughts: You picture yourself having dinner that evening, then wonder if you've been eating too much fast food recently, then notice the faint music playing from another passenger's headphones, and that reminds you of a song you've heard at a party the night before.

This is sort of an example of your thoughts are moving freely. You know, they can also move freely around a particular topic such as a current event, or you know, something you're currently interested in. For example, you think of the bike you just bought, then think yourself biking down a trail next weekend, then picture your friend riding next to you, then remember the first bike you got for your 10th birthday and so on. So this is an example where you know, it's sharing the same topic but it's still moving freely in that range. Thought can also move freely in the external environment. So you might be hiking on a forest trail, you notice your mind may shift from the gravel on the path in front of you, to a slug crawling up a stump, to a leaf floating in a puddle. You understand.

So here we're going to pause the video, and we're going to get you to come up with your own example of thoughts when your mind was moving about freely. The example should be different from the ones that were just mentioned.

A.3. Explanation of Task-unrelatedness

Were your thoughts about something other than what you were doing? So what you're currently doing can include

- Physical activities such as taking a walk, washing dishes, playing sports
- Could be mental activities such as reading an article, studying for your test, solving a math problem, planning your weekend
- Could be social activities such as having a conversation, dancing.
- It can also be, you know, watching TV, going to the movies, other leisure activities.

When your thoughts are about something other than what you are doing

- You are thinking about something other than your current activity
- You might be distracted from your current activity by something sensory (something you hear, see, smell, feel)
- You might be distracted from your current activity by internal thoughts that just popped in your head (memories, images, emotions, internal speech).

Pause the video here and come up with your own example of times when you were thinking about something other than what you were doing.

A.4. Explanation of awareness of surroundings

Were you aware of your surroundings? It's a pretty basic one. When you are aware of your surroundings, when your mind is turned toward things in the external environment, such as

- What you are seeing
- What you are hearing
- What you are touching
- What you are smelling

In contrast, when you are unaware of your surroundings, your mind might be totally full of internal thoughts, such as

- Memories
- Images
- Emotions
- Abstract thoughts

- The voice in your head
- And so on…

And, just to make it clear, there are some times when you are having external thoughts but there's still some amount of attention that is aware of your surroundings. Let say you're walking and thinking about something at the same time.

We're going to pause the video here. Come up with an example of times when you were aware of your surroundings.

Appendix B. Probe questions

Participants attended an in-person session to receive instructions on how to answer each question.

1. Was your mind moving about freely?
2. Were you thinking about something other than what you were doing?
3. Were you aware of your surroundings?
4. Were you actively directing your thoughts?
5. Was something you wanted or needed (to do) pulling your attention?*
6. Was something emotional pulling your attention?
7. Was something perceptual pulling your attention?
8. If you tried to disengage from your thoughts, would it be mentally difficult to do so?*Due to software error, participants did not answer this question on every trial.

Appendix C

Scatter plot representing the inter-individual correlations between task-unrelatedness and freedom of movement (see Fig. C1).

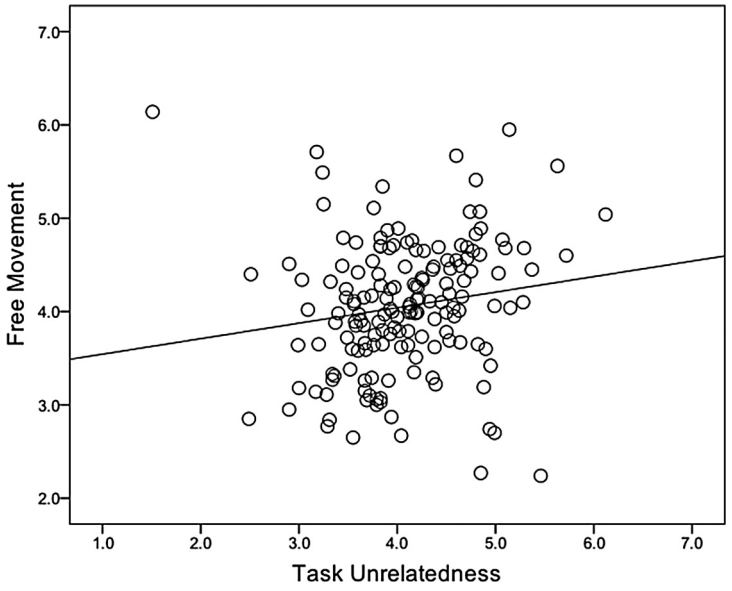

Fig. C1. Note. Both variables (raw data) were averaged across all probes for each participant, then correlated at the subject-level (N = 165).

Appendix D

Descriptives and p-values for each of the four categories using z-score standardized data. Data represents the average proportion of responses that fell in each category.

	Pred. if off-task/perc. awareness is equiv. with freely-moving	*M*	*SD*	*t*	*p*	95% CI (*M*)	
						Lower	Upper
Free movement and task-relatedness							
Freely-moving – Off-task	Yes	0.289	0.144	25.8	0.000	0.267	0.311
Constrained – Off-task	No	0.202	0.146	17.7	0.000	0.179	0.224
Constrained – On-task	Yes	0.279	0.140	25.7	0.000	0.258	0.301
Freely-moving – On-task	No	0.218	0.138	20.3	0.000	0.197	0.239
Falls on Median	–	0.012	0.066				
Free movement and perceptual awareness							
Constrained – Unware	No	0.246	0.133	23.8	0.000	0.226	0.267
Freely-moving – Unaware	Yes	0.242	0.145	21.5	0.000	0.220	0.265
Freely-moving – Aware	No	0.261	0.145	23.1	0.000	0.239	0.283
Constrained – Aware	Yes	0.230	0.169	17.5	0.000	0.204	0.256
Falls on Median	–	0.020	0.094				

Notes. Pred. = predicted; equiv. = equivalent; Results showing one-sample *t*-tests compared to 0; df = 164 for all cases.

Appendix E

Scatter plot representing the inter-individual correlations between awareness of surroundings and freedom of movement (see Fig. E1).

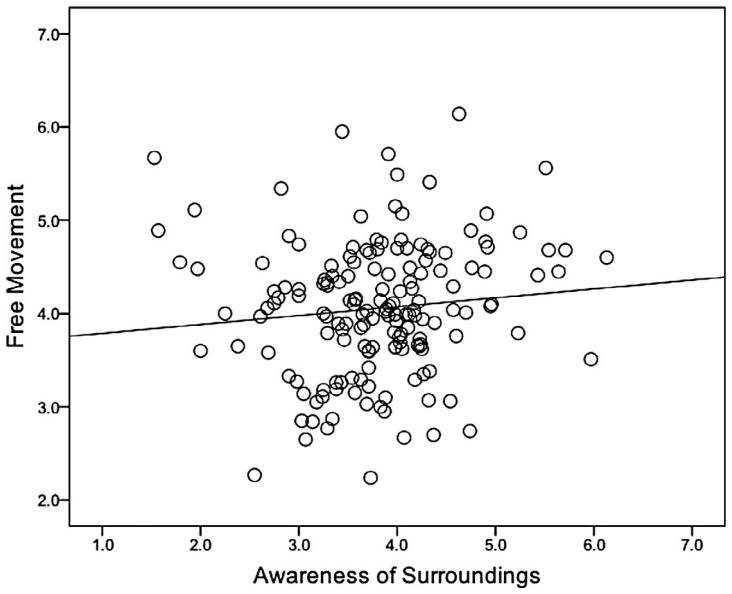

Fig. E1. Note. Here both variables were averaged across all probes for each participant, then correlated at the subject-level (N = 165).

Appendix F

Descriptives and p-values for median-split with raw data. Data represents the average proportion of responses that fell in each category.

	Pred. if off-task/perc. awareness is equiv. with freely-moving	*M*	*SD*	*t*	*p*	95% CI (*M*)	
						Lower	Upper
Free movement and task-relatedness							
Freely-moving – Off-task	Yes	0.208	0.135	19.7	0.000	0.187	0.228
Constrained – Off-task	No	0.118	0.104	14.6	0.000	0.102	0.134
Constrained – On-task	Yes	0.197	0.135	18.7	0.000	0.176	0.218
Freely-moving – On-task	No	0.111	0.110	12.9	0.000	0.094	0.128
Falls on Median	–	0.367	0.169				
Free movement and perceptual awareness							
Constrained – Unware	No	0.191	0.147	16.7	0.000	0.168	0.213
Freely-moving – Unware	Yes	0.143	0.130	14.2	0.000	0.123	0.163
Freely-moving – Aware	No	0.149	0.133	14.4	0.000	0.129	0.170
Constrained – Aware	Yes	0.107	0.085	16.2	0.000	0.094	0.213
Falls on Median	–	0.410	0.164				

Notes. Pred. = predicted; equiv. = equivalent; Results showing one-sample *t*-tests compared to 0; df = 164 for all cases.

Appendix G

Scatter plot for Freely Moving thought and Task-unrelatedness: Z-score standardized by participant probe level data (see Fig. G1).

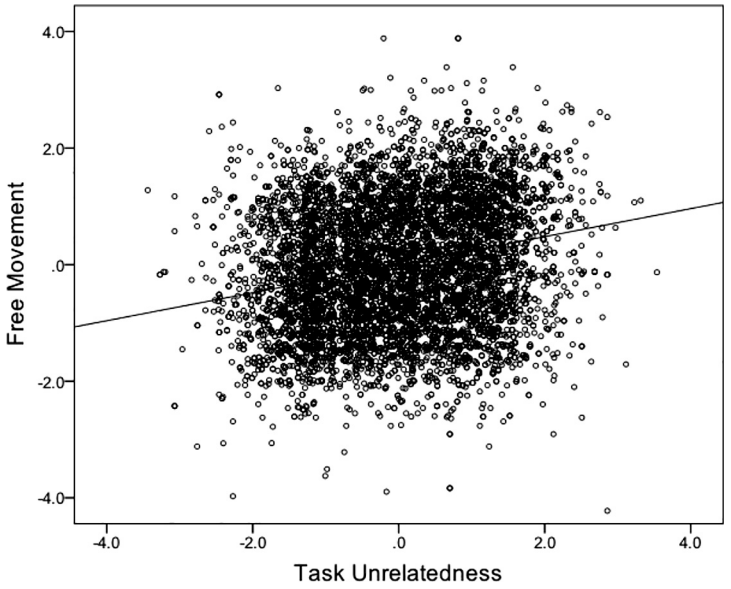

Fig. G1. Scatter plot for freely moving thought and task-unrelatedness computed using probe level data. Values were z-score standardized at the participant level.

Appendix H

Scatter plot for Freely Moving thought and Perceptual Awareness: Z-score standardized by participant probe level data (see Fig. H1).

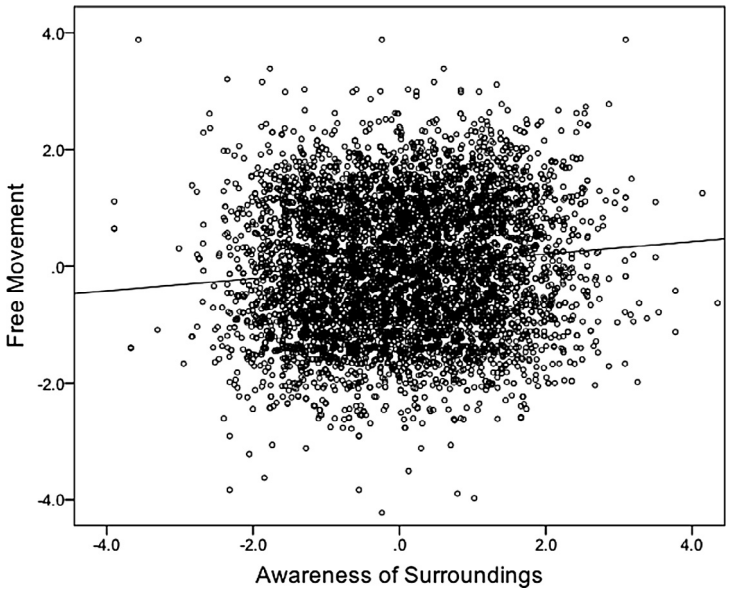

Fig. H1. Scatter plot for freely moving thought and perceptual awareness computed using probe level data. Values were z-score standardized at the participant level.

Appendix I

Correlations between average values (inter-individual correlations) of Freedom of Thought, Task-unrelatedness, and Perceptual Awareness

N = 165	Freedom of movement	Task-unrelatedness	Perceptual awareness
Freedom of movement	–		
Task-unrelatedness	0.156	–	
Perceptual awareness	0.107	0.210	–

Appendix J

Scatter density plots using raw probe level data (see Fig. J1).

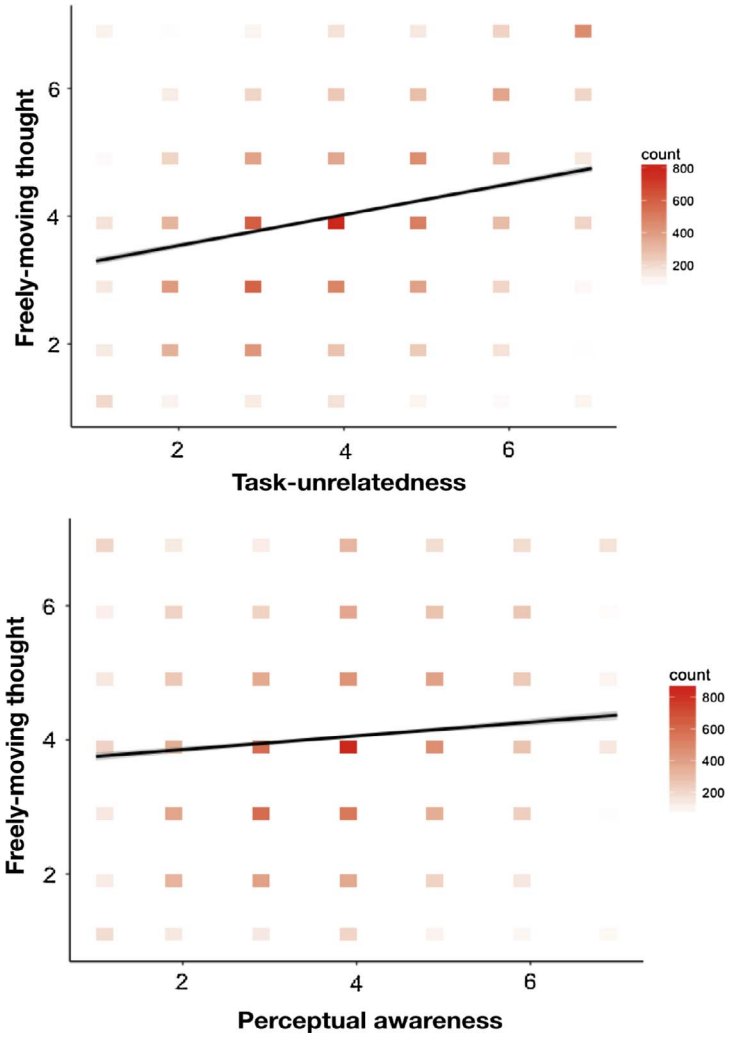

Fig. J1. Scatter density plot for freely moving thought versus task-unrelatedness and perceptual awareness computed using raw probe level data. Red indicates higher density at respective coordinates.

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