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How Task-Unrelated and Freely Moving Thought Relate to Affect: Evidence for Dissociable Patterns in Everyday Life

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Much of our knowledge about the correlates of mind-wandering comes from assessing task-unrelated thought. Less is known about the correlates of freely moving thought, a dimension that assesses the degree to which thoughts arise and unfold with low levels of guidance or constraints. Task-unrelated thought is consistently associated with more negative affective valence compared with being on task; however, it is unclear whether freely moving thought shares the same relationship with affect. We conducted two ecological momentary assessment studies in the context of everyday life and found that the two dimensions have different affective correlates. In Study 1, task-unrelated thought was associated with less positive concurrent valence than being on-task. However, freely moving thought was associated with more positive concurrent valence and was predictive of more positive valence at a subsequent timepoint. Freely moving thought, but not task-unrelated thought, also positively predicted concurrent arousal. Computational sentiment analyses of participants' thought descriptions offered convergent evidence of differential relationships between the two thought dimensions and affect. Study 2 used different measurement scales to assess whether (a) the pattern of findings replicated and (b) if the effects were robust to changes in measurement. The main findings were replicated: task-unrelated thought was negatively associated with concurrent valence, whereas freely moving thought was positively associated with concurrent valence. However, freely moving thought did not predict subsequent valence and was not related to concurrent arousal. The most robust findings related to concurrent valence. Although mind-wandering has acquired a relatively negative reputation to date, our findings suggest that there might be positive aspects that remain unexplored.

Keywords: mind-wandering, affect, task-unrelated thought, freely moving thought, valence

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The study of mind-wandering has grown considerably in recent years—a growth that is matched by an increasing recognition of its cognitive, affective, and clinical relevance. To date, an overwhelming majority of the work in this area (approximately 95% of published results) has conceptualized mind-wandering as *task-unrelated thought*, or when thoughts shift away from one's current task (Mills et al., 2018). Task-unrelated thought indeed occurs with remarkable frequency in our waking lives—an estimated 30% to 50% of the time (Killingsworth & Gilbert, 2010; Klinger & Cox, 1987; but see Seli et al., 2018) and has been related to critical aspects of our everyday lives including cognitive performance (Randall et al., 2014), affective states (Killingsworth & Gilbert, 2010; Ruby et al., 2013), clinical alterations in thought (Marchetti et al., 2016; Ottaviani, Shahabi, et al., 2015; Seli et al., 2017), and educational outcomes (Mills et al., 2017; Smallwood et al., 2007).

Although task-unrelated thought has been a primary focus of empirical investigations until now, investigations into the *freely moving* thought dimension have recently begun as well (Mills et al., 2018; Smith et al., 2018).[1] Freely moving thought occurs when thoughts move from one thing to another with relatively low guidance or constraints (Christoff et al., 2016; Irving, 2016). Similar to task-unrelated thought, freely moving thought occurs in over 30% of waking thoughts (Mills et al., 2018; Smith et al., 2018). However, task-unrelated and freely moving

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[1] Notwithstanding recent theoretical debates on the definitions of mind-wandering (Christoff et al., 2018; Seli, Kane, Metzinger, et al., 2018; Seli, Kane, Smallwood, et al., 2018), the current article focuses on the empirical correlates of two different dimensions thought that are both important for scientific inquiry. Here we do not claim that either dimension is the necessary and sufficient characteristic for mind-wandering.

thoughts are only weakly related ($r < .25$; Mills et al., 2018), indicating that they might represent different dimensions of thought. But do task-unrelated thought and freely moving thought have dissociable functional correlates and consequences in everyday life? This question has remained unexamined so far.

One of the most stable and widely replicated correlates of task-unrelated thought to date is its negative relationship with concurrent affective valence: off-task thoughts are generally less positive than on-task thoughts (Hobbiss et al., 2019; Killingsworth & Gilbert, 2010; Song & Wang, 2012). Task-unrelated thought has also been claimed to lead to more negative subjective valence in the future (Killingsworth & Gilbert, 2010). Recent multidimensional experience sampling studies have since drawn attention to the idea that relationship between task-unrelated thought and affect might often be driven by thought content (Engert et al., 2014; Sormaz et al., 2018; Wang et al., 2018). For example, task-unrelated thought might only be related to negative affect in certain situations, such as when thinking about the past or sad content (Poerio et al., 2013; Ruby et al., 2013; Wang et al., 2018). Task-unrelated thought might even lead to more positive affect in some situations, as when the content of thought is interesting (Franklin, Mrazek, et al., 2013) or pleasant (Welz et al., 2018).

Regardless of content, however, task-unrelated thought is still frequently related to less positive ratings of valence compared with on-task thought in the literature. One possible explanation for this is that task-unrelated thought might be a failure of the executive-control system to inhibit interfering thoughts (McVay & Kane, 2009, 2010); such thoughts might therefore be subjectively appraised as more negative because of the attentional failure itself. In addition, the content of the task-unrelated thought might involve more negative or neutral content, such as current concerns that are unrelated to the current task (Klinger et al., 1980; Klinger & Cox, 2004; Watkins, 2008).

Although task focus and other aspects of thought content are undoubtedly important, dynamic dimensions of thought might reveal additional clues behind the relationship between mind-wandering and affect. Ottaviani and colleagues (Ottaviani et al., 2013; Ottaviani, Medea, et al., 2015), for example, have shown that perseverative thinking (i.e., as when ruminating or worrying) is an inflexible form of thinking with negative affective consequences. Perseverative thinking is thought to be influenced by "automatic" or habitual neurocognitive sources that guide one's thoughts toward particularly salient topics, outside of one's deliberate control (Christoff et al., 2016). People might also "deliberately" direct their thoughts toward particular topics, stabilizing attention over time, as when engaging in goal-directed cognition (Christoff et al., 2016). In contrast to these automatic and deliberate styles of thinking, freely moving thoughts are thought to 'move' with little constraints from one thought to the next, irrespective of their specific content (Christoff et al., 2016). Notably, a key theoretical difference between task-unrelated and freely moving dimensions is that task-unrelated thought is focused on momentary content, whereas freely moving thought is focused on the dynamics of the thought stream. Elucidating the affective correlates of this freely moving dimension of thought marks a key objective of the present article.

Given that freely moving thought is likely to encompass an increased range of mental states, an open question is whether freely moving thought might share a positive relationship with affective valence. This idea is based on Fredrickson's (1998, 2001) broaden-and-build theory where positive affect is associated with an increased attentional scope and cognitive broadening. Support for this theory comes from multiple studies reporting that positive affect is related to an increased scope of attention across multiple cognitive domains—including visual selective attention (Fredrickson & Branigan, 2005; Rowe et al., 2007), semantic search (remote associates task; Rowe et al., 2007), thought-action repertoires (Fredrickson & Branigan, 2005), divergent thinking (Yamada & Nagai, 2015), as well as increased association memory (Madan et al., 2019). The broaden-and-build perspective might therefore predict that positive affect would be likely to occur in combination with less constrained, or freely moving, thought that encompasses a broader topic space and more flexible movement between mental states. Based on this idea, we predict that freely moving thought will share a positive relationship with affective valence compared with the negative relationship often observed for task-unrelated thought.

Notably, this prediction diverges from the typical negative reputation mind-wandering has accrued over time based on its relationships with valence and performance, captured through scientific titles such as, "A wandering mind is an unhappy mind" (Killingsworth & Gilbert, 2010, p. 1). This reputation, however, was amassed through the study of task-unrelated thought, and it is therefore possible that other dimensions, such as the freely moving dimension, will have dissociable relationships with affect. Here we use ecological momentary assessment (EMA) to test whether different dimensions of mind-wandering have beneficial correlates in daily life.

In addition to our main a priori predictions about the valence of one's affective state, we included a second dimension of affect—subjective experiences of arousal—as an exploratory line of research. Common theories of affect highlight two key orthogonal dimensions that describe affective states (Posner et al., 2005; Russell, 1980): valence (unpleasant to pleasant) and arousal (calm/relaxed to active/energetic). To date, however, previous research has dominantly focused on subjective feelings of valence using a unidimensional scale (Killingsworth & Gilbert, 2010; Song & Wang, 2012). A few notable exceptions point to the idea that physiological arousal (measured via pupillometry) might be related to task-unrelated thought. Yet the direction of the relationship has been inconsistent in the literature (Franklin, Broadway, et al., 2013; Mittner et al., 2014; Unsworth & Robison, 2018), leading some researchers to suggest that that the relationship might depend on why a person goes off-task in the first place. For example, the relationship might, in part, be dependent on the task: task-unrelated thought is associated with lower physiological arousal when completing externally demanding tasks, but this relationship is not observed in tasks that demand internally oriented attention (Unsworth & Robison, 2018). Whereas the aforementioned studies focused on physiological arousal through pupillometry measures, here we take an exploratory look at the relationships between subjective ratings of arousal and task-unrelated thought and freely moving thought.

Study 1

Method

All research practices described here were approved by the Institutional Review Board (IRB) at the University of New Hampshire.

Participants

In total, 79 undergraduate students (78% female; M_{age} = 19.3, SD_{age} = 1.26) at the University of New Hampshire participated for course credit. Sample size estimates were calculated a priori based on consistent differences in average valence ratings for on versus off-task thought. G*Power was used to determine that 71 participants were needed to detect an effect size of .3 with .80 power and alpha set to .05 (Faul et al., 2007). In order to account for attrition rates, we attempted to collect data from 85 participants. However, six people did not show up for the training session. Anonymized data is available upon request and approval from the original IRB.

Key Variables

Below we describe the key constructs measured in our study.

Task-Unrelated Thought. In Study 1, we adopted the same dichotomous probing strategy as two previous studies comparing task-unrelated thought and affect in everyday life (Killingsworth & Gilbert, 2010; Song & Wang, 2012). In this method, task-unrelated thought is considered to be thinking about anything other than what you are currently doing and is measured using a Yes or No response. We initially chose to mimic this probing strategy in order to make more direct comparisons with previous findings related to task-unrelated thought and affect (but see Study 2 for a change in probing strategy).

Freely Moving Thought. We adopted the same approach as two of our previous studies assessing freely moving thought in everyday life (Mills et al., 2018; Smith et al., 2018). Freely moving thought was defined as thoughts that have relatively low guidance or constraints and was measured on a 6-point scale.

Affect. Previous research examining task-unrelated thought has predominantly focused on subjective valence using a unidimensional scale (Killingsworth & Gilbert, 2010; Song & Wang, 2012). Here we adopt the circumplex model of affect (Russell, 1980), which posed that affective states can be explained by two orthogonal dimensions: valence (unpleasant to pleasant) and arousal (calm/relaxed to active/energetic). We expand on previous studies by examining these two dimensions of affect simultaneously, rather than solely measuring the valence dimension of affect. Both valence and arousal were measured on scales ranging from 1 to 9, as is common practice in the literature.

Materials and Training

An open-source application (https://github.com/AndrewRPorter/ping-app), freely available on GitHub, was built for the purposes of this study to allow us to send and receive thought probes via text messages. Text messages were sent directly to participants' cell phones. The study began with a 35-min training session. Groups of participants (10 to 20 at a time) met in a classroom to give informed consent and receive detailed instructions regarding the task. All training sessions were conducted by the first author using a PowerPoint presentation to ensure consistency.

Instructions were similar to the ones used in Mills et al. (2018). First, participants were instructed that when they receive a probe on their phone, they should take a mental snapshot of what they were thinking about just before they saw the probe. Participants were instructed to use that mental snapshot to answer the following five questions included in each probe:

1. How are you feeling right now in terms of valence (negative to positive)? Answer on a scale from 1 (*very negative*) to 9 (*very positive*).

   Explanation: Your feelings of valence can vary in terms of degree, which we are asking you to rate on a scale of 1 to 9. For example, 1 would be *very negative feelings*, whereas 9 would be *very positive feelings*.

2. How are you feeling right now in terms of arousal (calm to active)? Answer on a scale from 1 (*very calm*) to 9 (*very active*).

   Explanation: Your feelings of arousal can vary in terms of degree, which we are asking you to rate on a scale of 1 to 9. For example, 1 would be *very calm/sleepy*, whereas 9 would be *very active/excited/fidgety*.

3. Are you thinking about something other than what are you currently doing? Answer with either a *Y* or an *N*.

   Explanation: Your thoughts are considered off-task when you begin to think about anything other than what you are currently doing. This is natural and should not alarm you.

4. Are your thoughts wandering around freely? Answer on a scale from 1 (*not at all*) to 6 (*very much so*).

   Explanation: Your thoughts move around freely when there is no overarching purpose or direction to your thinking. Instead, your thoughts drift from one thing to another without focusing on anything for too long.

5. Please provide a brief description of your most recent stream of thought based on the mental snapshot. (Note that this was a verification question to ensure that participants were not answering randomly.)

Each question was described in detail one at a time. Explanations were provided before pausing for questions from the group. Participants were then quizzed as a group to ensure they understood the questions and probing methodology. Finally, incentives for participation were specified at the end of the power-point: one credit was given for attending the training/informed consent session, a second credit was given for answering at least 60% of the probes (i.e., metric for basic compliance), and a third credit was given for answering over 80% of the probes.

Procedure

The probe questions were delivered through text messages sent directly to participants' personal cell phones; participants replied to each question through a text message that was logged on a secure external server. As soon as an answer was received, the next question was triggered such that the probe set mimicked a text conversation. Questions appeared in the same order each time to reduce confusion. Each probe took less than a minute to respond.

Probe sets (i.e., the set of probe questions) were delivered between 9 a.m. and 9 p.m. To ensure random, yet evenly distributed probing throughout the day, the 12-hr period was parsed into three time periods: 9 a.m. to 1 p.m., 1 p.m. to 5 p.m., and 5 p.m. to 9 p.m. Probe sets were randomly triggered within each timeperiod. This probing strategy was chosen to ensure ample variability in probing times across the day (see the online supplementary material for a plot of probe times across the day).

We also examined how mind-wandering at a given timepoint (t_0) influences affect at a subsequent timepoint (t_1). Each randomly delivered probe was "paired" with a second probe that was delivered 8 min to 12 min after the first probe set was completed. A timer for the second probe was initiated after the last question was answered in t_0. This lag time is consistent with the procedures used in previous studies; Killingsworth and Gilbert (2010) used multiple hour delays; however, Poerio et al. (2013) suggested that shorter probe times—on the order of 15 min—might be more precise for lag analyses involving affect. Two probe sets occurred in each of the three time periods, yielding six probes per day per person.

Participants completed the study in one of two different groups, one week apart. The training sessions took place on Wednesdays, and probes began on Thursdays. In Group 1, participants answered probes from Thursday to Monday, receiving a total of 30 probe sets. In Group 2, participants answered probes from Thursday to Sunday, receiving a total of 24 probe sets (probes on Monday were not delivered due to an external server error causing a shutdown).

Data Processing

A total of 1,780 probes were answered. On average, participants responded to 77.5% ($SD = 13.8\%$) of the probes. In total, 3.8% of the probe answers contained a response outside of the allowed parameters (e.g., answering 0 for a scale of 1 to 9); those probes were excluded from data analysis. Additionally, we removed six participants who were considered noncompliant—that is, they did not respond to enough probes to receive credit for participating (responding to less than 60% of probes). This removal process follows the compliance criterion of similar experience sampling studies (Shackman et al., 2018; Takano et al., 2013) given the ecological validity of experience sampling depends on the ability to sample a wide enough range of activities and situations (Scollon et al., 2003), while ensuring a large enough intraindividual sample which is critical for the power of mixed-effects approaches.

Analyses proceeded with 73 participants (1,656 total probe responses). Intraclass correlations for all variables can be found in Table 1, representing adequate within-subject variability in probe responses. We also note that patterns remain the same even when the noncompliant participants are included.

Analytical Approach

We assessed the relationships between task-unrelated thought, freely moving thought, and affect using mixed-effects linear regressions using the lme4 package in *R* (Bates et al., 2014). We used the raw response data for analyses, and report standardized regression values and 95% confidence intervals (CIs) to facilitate effect size comparison across models. Models were estimated using restricted maximum likelihood estimation with an unstructured covariance structure. All models were fitted with a random intercept only model structure (participant as random effect) which helps account for the within-subject variance in ratings across participants.[2] For analyses described in the following text, the dependent variable was affective dimension (valence or arousal). Models contained two key fixed effects: the two thought dimensions (task-unrelated thought and freely moving thought). Significance testing was completed with a two-tailed alpha of .05 using the chi-square test from the car package in R (Fox et al., 2013). Standardized regression coefficients and 95% of CIs were computed using the effectsize package and R-square values for the fixed effects were computed using the MuMIn package in R, following the recommendations of Nakagawa and Schielzeth (2013). Finally, we are also interested in drawing some comparisons about the relationships between task-unrelated thought and freely moving thought. We adopted the approach recommended by Cumming (2009), whereby the 95% CIs of the standardized regression coefficients (ß) are compared. We adopt a very conservative version of this approach by only claiming dissociation if the intervals involve 0% overlap (Cumming, 2009).

Table 1
Intraclass Correlations (ICCs) for Both Timepoints (t_0 and t_1) Across Studies 1 and 2

Variable	Study 1	Study 2
Affect		
Valence t_0	.199	.165
Arousal t_0	.124	.142
Valence t_1	.195	.15
Arousal t_1	.096	.13
Thought		
Task-unrelated thought t_0	.132	.227
Freely moving thought t_0	.335	.224
Task-unrelated thought t_1	.136	.230
Freely moving thought t_1	.304	.212

Results

Relationship Between Task-Unrelated Thought and Freely Moving Thought

On average, participants reported being off-task 59.6% of the time ($SD = 20.1$) across both timepoints. On a scale of 1 to 6, the average overall rating for freely moving thought was 2.89 ($SD =$

[2] Random slopes were not included in the models described here. However, for completeness, we report that when the two thought dimensions were added as random slopes, model fits did not improve—Bayesian information criterion values were lower without random slopes forall models. Recommendations suggest this fit comparison be used to decide on whether more complex model structures should be used (Bell et al., 2019). However, the pattern of results does not change when random slopes are added, yet the more complex model structure did result in some overfitted models.

.910). Whereas these numbers reflect all ratings, descriptive statistics for all key variables are provided in Table 2, broken down by the two separate timepoints.

Previous research shows that task-unrelated thought and freely moving are positively but weakly related (Mills et al., 2018; ß = .247). Here we replicated this finding: a mixed effects linear regression revealed that the two dimensions were positively related to one another (ß = .31, 95% CI [.27, .35]), $\chi^2(1) = 229$, $p < .001$. Task-unrelated thought (dichotomous fixed effect) explained less than 10% of the variance in freely moving thought (r^2 of fixed effect = .097). Based on this relationship, both variables were included as predictors in the same model to examine their unique influence on affect without concern of multicollinearity.

Relationships With Concurrent Affective State

A summary of the full regression results is shown in Table 3.

Valence. Task-unrelated thought and freely moving thought had differential relationships with concurrent subjective valence (i.e., one's current affective state): valence was negatively related to task-unrelated thought (ß = −.07), $\chi^2(1) = 8.63$, $p = .003$, but positively related to freely moving thought (ß = .12), $\chi^2(1) = 18.8$, $p < .001$. The negative relationship found for task-unrelated thought replicates previous work by Killingsworth and Gilbert (2010): off-task thought is less positive than on-task thought. However, freely moving thought was positively related to valence, providing initial evidence that the two dimensions might have dissociable correlates, especially with respect to ongoing affective states (see Table 3 and Figure 1 for evidence of nonoverlapping 95% CIs).

Arousal. Task-unrelated thought was not significantly related to arousal (ß = −.04), $\chi^2(1) = 1.96$, p = .162. In contrast, freely moving thought was positively related to arousal (ß = .08), $\chi^2(1) = 8.12$, $p = .004$.

Relationships With Subsequent Affective State

Previous research suggests that task-unrelated thought might lead to more negatively valenced affective states at a subsequent timepoint, which has been used as the basis for proposals that "mind-wandering is generally the cause, and not merely the consequence of unhappiness" (Killingsworth & Gilbert, 2010, p. 1). Here we explored if the two dimensions at t_0 (the first timepoint) are predictive of affect (valence and arousal) at t_1 (subsequent timepoint). We only analyzed probes where participants responded to both t_0 and t_1 in the same time interval (deployed 8 min to 12 min apart), yielding 787 probes from all 73 participants. Lag analyses across longer intervals throughout the day or across days (e.g., overnight) were not considered, as we were interested in the specific time-locked points of t_0 and t_1 afforded by our experience sampling schedule.

Valence. Similar to the concurrent affect models, valence at t_1 was regressed on task-unrelated thought and freely moving thought. Valence at t_0 was also included in the model in order to understand the unique influence of the two dimensions after controlling for the initial valence rating. Valence at t_0 was positively predictive of valence at t_1 (ß = .47), $\chi^2(1) = 222$, $p < .001$, consistent with prior research (Killingsworth & Gilbert, 2010).

Task-unrelated thought at t_0 was not significantly related to valence at t_1 (ß = −.02), $\chi^2(1) = .230$, $p = .632$. These findings do not align with previous research; Killingsworth and Gilbert (2010) found that task-unrelated at t_0 was negatively predictive of valence at t_1 when assessed at more distant points in time compared with the present study. In the present study, freely moving thought at t_0 was, however, a significant positive predictor of valence at t_1 even after controlling for valence at t_0 (ß = .12), $\chi^2(1) = 11.2$, $p = .001$.

Valence at t_0 did not predict task-unrelated thought at t_1 (ß = −.02), $\chi^2(1) = .316$, $p = .574$, or freely moving thought at t_1 (ß = .00), $\chi^2(1) < .001$, $p = .999$. These effects are in line with previous work, where valence was not a strong predictor of subsequent task-unrelated thought (Killingsworth & Gilbert, 2010); here we find that freely moving thought follows a similar pattern.

Arousal. Task-unrelated thought and freely moving thought at t_0 were not predictive of arousal at t_1 (ps > .1; see Table 3 for model details). Similarly, arousal at t_0 was not predictive of either task-unrelated thought at t_1 (ß = −.01), $\chi^2(1) = .035$, $p = .853$, or freely moving thought at t_1 (ß = .05), $\chi^2(1) = 2.13$, $p = .145$.

Possible Interaction Effects

We did not make any a priori predictions for interaction effects between task-unrelated and freely moving thought. However, for completeness, and given our claims of dissociation among the two dimensions, we tested the possibility that the relationships described above might be more appropriately described through interactions. Models were constructed similar to the ones described above with the addition of an interaction term (Task-Unrelated Thought × Freely

Table 2
Overall Descriptive Statistics Study 1

	Study 1		Study 2	
	Timepoint 0	Timepoint 1	Timepoint 0	Timepoint 1
Variable	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Total probes answered	23.4 (4.04)		16.1 (2.10)	
Valence [S1: 1–9; S2: 1–7]	5.63 (1.09)	5.52 (1.02)	5.01 (.742)	5.00 (.781)
Arousal [S1: 1–9; S2: 1–7]	4.02 (.099)	4.02 (.862)	3.72 (.831)	3.70 (.858)
Off-task thought [S1: proportion; S2: 1–7]	.594 (.238)	.606 (.228)	3.93 (1.21)	3.91 (1.13)
Freely moving thought [S1: 1–6; S2: 1–7]	2.90 (.976)	2.92 (.924)	3.93 (1.10)	3.88 (1.08)

Note. Measurement scales in brackets. Note there were measurement changes across the two studies to examine whether effects were robust despite different scales. Valence and arousal changed from a 9-point scale in Study 1 (S1) to a 7-point scale in Study 2 (S2). Task-unrelated thought was a dichotomous yes/no answer in Study 1, and it was on a scale from 1 to 7 in Study 2. Freely moving thought was on a scale from 1 to 6 in Study 1 and a similar 1 to 7 scale for Study 2.

Table 3
Summary of Model Results Across Both Studies

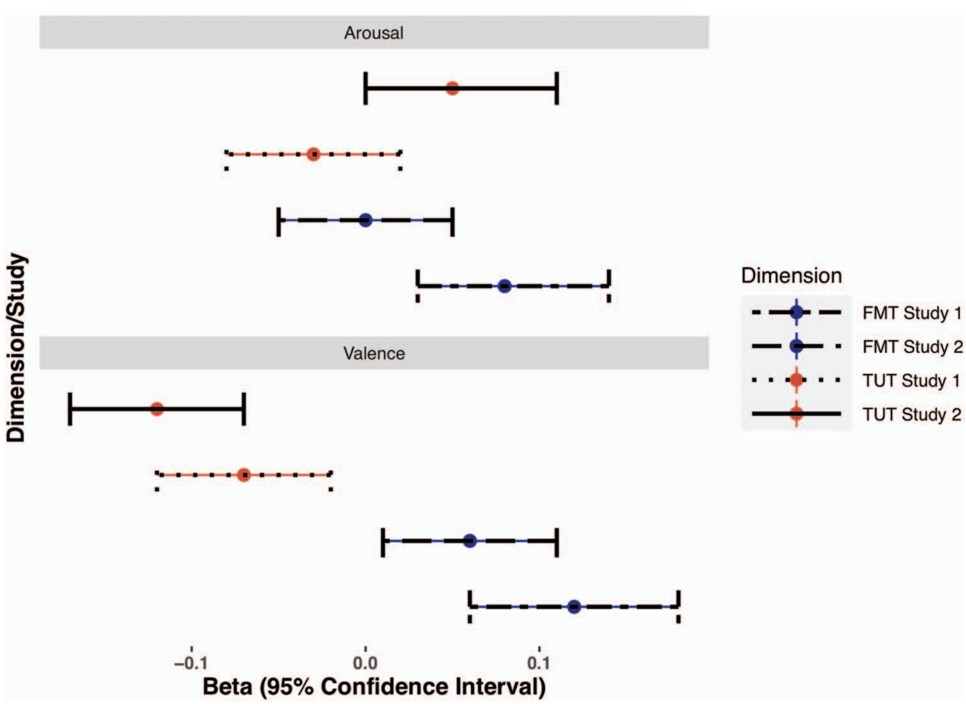
	Concurrent affect				Subsequent affect			
	Valence		Arousal		Valence		Arousal	
Variable	ß [95% CI]	*p*	ß [95% CI]	*p*	ß [95% CI]	*p*	ß [95% CI]	*p*
				Study 1				
TUT	−.07 [−.12, −.02]	.003	−.04 [−.09, .01]	.162	−.02 [−.08, .05]	.632	.00 [−.06, .06]	.930
FMT	.12 [.06, .18]	<.001	.08 [.03, .14]	.004	.12 [.05, .18]	.001	.01 [−.05, .08]	.662
Valence t_0					.47 [.41, .53]	<.001		
Arousal t_0							.56 [.51, .62]	<.001
				Study 2				
TUT	−.12 [−.18, −.07]	<.001	.06 [.00, .11]	.040	.01 [−.06, .07]	.783	.02 [−.04, .09]	.471
FMT	.06 [.01, .12]	.016	.00 [−.06, .05]	.855	−.03 [−.10, .03]	.302	.02 [−.05, .08]	.560
Valence t_0					.53 [.47, .59]	<.001		
Arousal t_0							.53 [.47, .59]	<.001

Note. Beta values for task-unrelated thought (TUT) in Study 1 represent the mean difference of off versus on task in standard deviation units (dichotomous probe), whereas the TUT in Study 2 was collected on a continuous scale. FMT = freely moving thought; t_0 = first timepoint in each probe cycle, which was used a covariate to account for affect as the first timepoint.

Moving Thought) included. A full description of all models is included in the online supplementary materials. There were no significant interactions for concurrent valence ($p = .523$) or subsequent valence ($p = .450$), suggesting that the dissociations reported above did not depend on a combination of the two thought dimensions.

There was evidence of a single interaction between task-unrelated thought and freely moving thought for concurrent arousal, $\chi^2(1) = 7.18$, $p = .007$. Two post hoc models revealed that when participants reported being off task, freely moving thought was not related to arousal (ß = .03), $\chi^2(1) = .546$, $p = .460$. However, freely moving

Figure 1
Beta Values With 95% CIs for the Relationships Between Affect and Task-Unrelated Thought and Freely Moving Thought Across Both Studies



Note. The 95% confidence intervals (CIs) for valence do not overlap, suggesting some evidence for dissociation. The same dissociation is not observed for arousal. TUT = task-unrelated thought; FMT = freely moving thought. See the online article for the color version of this figure.

thought was positively related to arousal when participants reported being on-task (ß = .17), $\chi^2(1) = 16.20$, $p < .001$. The interaction was not observed for subsequent arousal ($p = .201$).

Relationships With Language Descriptors of Thought: Convergent Validity

The open-ended responses were collected as a quality check to ensure that participants were thoughtfully (and not randomly) responding to the probes; participants were asked to type a brief description of their "mental snapshot." Their free-form responses also offer an additional source of data that can be used to assess convergent validity for the analyses reported above. We assessed if freely moving thought and task-unrelated thought shared differential relationships with the affective language participants used to describe their thoughts. We adopt a natural language processing (NLP) approach to quantitatively assess various aspects of sentiment for each thought description (for reviews and examples of applying NLP, see Jackson et al., 2020; McNamara & Graesser, 2012; Pennebaker et al., 2001, 2003). This method is modeled after other NLP research used to examine human behavior and cognition, including emotion (Jackson et al., 2019), comprehension (Magliano & Graesser, 2012) academic success (Pennebaker et al., 2014), and personality (Mairesse et al., 2007; Pennebaker & Graybeal, 2001) through language.

Freely moving thought was expected to be positively related to positive language (and less negative language), whereas task-unrelated thought was expected to be positively related to negative language (and less positive language). We assessed these relationships by using two validated algorithms to analyze the sentiment of the participants' language. First, we examined thoughts for the level of positivity and negativity expressed using the Valence Aware Dictionary of Sentiment Reasoning (VADER; Gilbert & Hutto, 2014). VADER uses a validated sentiment lexicon and a rule-based system for quantifying the intensity of the sentiment expressed. We extracted two key features from VADER for each thought description: positive and negative sentiment. Second, we examined the sentiment of various parts-of-speech components (adjectives, nouns, and verbs) from the Sentiment Analysis and Social Cognition Engine (SEANCE; Crossley et al., 2017). We extracted four components: positive adjectives, negative adjectives, positive nouns, and positive verbs. (It is worth noting that parallel negative nouns and negative verbs are not part of the component indices available in SEANCE.) We also note that these approaches do not necessarily capture the complete affective intention of the participant; however, they do avoid the potential bias of human coders. Finally, we also examined verbosity through a basic word count of each thought description. Verbosity was included as an exploratory dimension based on the prediction that freely moving thoughts might cover more topics and thus involve more content.

We analyzed each of the seven features by regressing them on task-unrelated thought and freely moving thought, similar to the analyses presented above (with participant as a random effect). Table 4 presents an overview of the models. In terms of convergent validity, we observed additional support for the idea that freely moving and task-unrelated thought have different qualities—which can also be observed via language. First, VADER indices suggest that task-unrelated thought is significantly less likely to contain positive words compared with on-task thought. No relationship was observed for freely moving thought for either positive or negative VADER scores. Second, SÉANCE indices shed some light on what parts of speech might differ across the two dimensions. Freely moving thought was negatively related to negative adjectives, whereas task-unrelated thought was positively related to negative adjectives (nonoverlapping 95% CI). Freely moving thought was also positively related to positive nouns; task-unrelated thought was not (though with overlapping CIs).

Finally, both measures were positively related to more verbosity. However, this relationship appears stronger for freely moving thought—providing some support for the idea that freely moving thoughts might involve more content through topic shifts (nonoverlapping 95% CI). These results were exploratory and should therefore be interpreted with caution, but nevertheless provide additional support for the potential differences between the two dimensions of interest.

Discussion

Study 1 provides preliminary evidence that task-unrelated thought and freely moving thought might have dissociable affective profiles. First, task-unrelated thought was associated with a less positive affective state (valence) than being on-task, converg-

Table 4

Relationships Among Thought Ratings and Computational Linguistic Features of Sentiment

	Freely moving thought			Task-unrelated thought		
Linguistic features	ß [95% CI]	χ^2	*p*	ß [95% CI]	χ^2	*p*
VADER						
Positive	−.01 [−.07, .04]	0.234	.628	−.06 [−.11, −.01]	4.75	.029
Negative	−.05 [−.11, .01]	3.07	.080	.01 [−.04, .07]	0.290	.590
SEANCE						
Positive adjectives	−.01 [−.06, .05]	0.032	.859	−.02 [−.07, .03]	0.496	.481
Negative adjectives	−.08 [−.14, −.03]	8.89	.003	.07 [.02, .12]	6.91	.009
Positive nouns	.07 [.01, .13]	6.02	.014	.01 [−.05, .06]	0.043	.837
Positive verbs	.02 [−.03, .07]	0.732	.393	−.02 [−.07, .04]	0.385	.535
Verbosity						
Words	.20 [.15, .25]	69.6	<.001	.09 [.05, .13]	16.9	<.001

Note. VADER = Valence Aware Dictionary of Sentiment Reasoning; SEANCE = Sentiment Analysis and Social Cognition Engine.

ing with results from a sentiment analysis of thought descriptions, whereas more freely moving thought was associated with more positive valence. Second, while task-unrelated thought did not correlate with arousal, freely moving thought showed a positive relationship with concurrent arousal. Third, freely moving thought at t_0 was associated with a more positive affective state at t_1.

Although these results provide a promising initial understanding of how two dimensions of thought might relate differently to affect, it is important to test whether these results will replicate in a new sample. We therefore conducted a second experience sampling study where the same four questions were administered on different numerical scales in order to assess whether (a) the findings replicated and (b) the effects were robust despite differential forms of measurement.

Study 2

Method

In the following text, we describe the methodological changes made in Study 2. First, a dichotomous response for the task-unrelated thought question was used in Study 1 (i.e., participants responded "yes" or "no"). This decision was made in order to follow the original methodology of Killingsworth and Gilbert (2010). However, recent research has shifted toward multilevel and numerical scales for participant responses (Mills et al., 2018; Seli, Beaty, Cheyne, et al., 2018; Wammes et al., 2019), which is supported by Seli et al.'s (2018) findings that dichotomous options do not necessarily capture the fact that people might not be completely engaged in or completely disengaged from their current task. Thus, the current study used the same question but with numerical response options ranging from 1 (*completely on task*) to 7 (*completely off task*), similar to the question used in Mills et al. (2018). Second, we changed all four questions to be on a 7-point scale in to allow for a midpoint (Mills et al., 2018). This was done to ensure that participants were not forced to provide an answer on one side of the 6-point scale. The freely moving thought, valence, and arousal questions were all asked on a 7-point scale. Third, we increased the number of participants in Study 2 due to the amount of variance accounted for by the random factor (i.e., participant) in Study 1 which will allow us to test if the patterns are robust with more between-subjects variability. Study 2 thus invited 130 total participants to participate in three days of experience sampling, such that the number of participants was increased without increasing the total number of possible probes across all participants (N = 18 probes per person in Study 2). Finally, we did not ask the thought description question in Study 2 to minimize time per probe.

Participants

In total, 122 undergraduate students (85% female; $M_{age} = 19$, $SD_{\text{age}} = .814$) at the University of New Hampshire participated for course credit. We attempted to collect data from 130, but eight people did not show up for the training session.

Materials and Training

With the exceptions mentioned above, other details of the study were the exact same. All participants went through the same 35-min training session. The only difference in the training sessions was that the response options were changed for the following questions:

1. How are you feeling right now in terms of valence (negative to positive)? Answer on a scale from 1 (*very negative*) to 7 (*very positive*).

2. How are you feeling right now in terms of arousal (calm to active)? Answer on a scale from 1 (*very calm*) to 7 (*very active*).

3. Are you thinking about something other than what are you currently doing? Answer on a scale of 1 (*completely on task*) to 7 (*completely off task*).

4. Are your thoughts wandering around freely? Answer on a scale from 1 (*not at all*) to 7 (*very much so*).

Procedure

Participants completed the study in one of two different groups, two weeks apart. The training sessions took place on Tuesday, and probes began on Thursdays. Both groups received probes from Thursday to Saturday (3 days) for up to 18 probes per person.

Data Processing

On average, participants responded to 84.6% (SD = 16.4%) of the probes. Similar to Study 1, less than 3% of the answers contained a response outside of the allowed parameters (e.g., answering 0 for a scale of 1 to 7) and were excluded from data analysis. We again removed noncompliant participants (n = 12) who did not respond to enough probes to receive credit (amounting to removing 5.3% of the total probe responses). We note that statistical patterns remain the same even when these participants were included.

Analytical Approach

The same modeling approach was adopted from Study 1.

Results

Relationship Between Task-Unrelated Thought and Freely Moving Thought

On a scale of 1 to 7, participants' overall average rating of task-unrelated thought was 3.93 (SD = 1.07), and the average rating for freely moving thought was 3.91 (SD = 1.01). See Table 2 for descriptive statistics of all key variables broken down by timepoint.

Similar to the results from Study 1, a mixed effects linear regression revealed that the two dimensions were positively related to one another (ß = .40), $\chi^2(1) = 318$, $p < .001$. Task-unrelated thought explained less than 16% of the variance in freely moving thought (r^2 of fixed effect = .158).

Relationships With Concurrent Affective State

Valence. The findings from Study 1 were replicated with respect to participants' subjective feelings of valence. Valence was, once again, negatively related to task-unrelated thought (ß = −.12), $\chi^2(1) = 21.9$, $p < .001$, and positively related to freely moving thought (ß = .06), $\chi^2(1) = 5.84$, $p = .016$.

Arousal. Findings from Study 1 were not replicated with respect to arousal. Task-unrelated thought was significantly related to arousal (ß = .06), $\chi^2(1) = 4.21$, $p = .040$. In contrast, freely moving thought was not significantly related to arousal (ß = .00), $\chi^2(1) = .034$, $p = .855$. These findings diverge from Study 1 where freely moving thought was found to significantly and positively relate to arousal.

Relationships With Subsequent Affective State

Results from Study 1 indicate that task-unrelated thought was not strongly related to future affect, but freely moving thought was positively related to valence at a future timepoint. We attempted to replicate these results by again testing if the two dimensions at t_0 (the first timepoint) are predictive of state affect (valence and arousal) at t_1 (subsequent timepoint). Similar to Study 1, both dimensions were included in the same model along with affect at t_0. Only probes where participants responded to both t_0 and t_1 in the same time interval were included, which yielded 841 probes from all 110 compliant participants.

Valence. Valence at t_0 was positively predictive of valence at t_1 (ß = .53), $\chi^2(1) = 322$, $p < .001$, consistent with Study 1. Once again, task-unrelated thought at t_0 was not significantly related to valence at t_1 (ß = .01), $\chi^2(1) = .076$, $p = .783$. Unlike the result from Study 1, freely moving thought at t_0 was not a significant predictor of valence at t_1 even after controlling for valence at t_0 (ß = −.03), $\chi^2(1) = 1.07$, $p = .302$. Valence at t_0 did not predict task-unrelated thought at t_1 (ß = −.04), $\chi^2(1) = 1.44$, $p = .230$, or freely moving thought at t_1 (ß = .01), $\chi^2(1) = .070$, $p = .791$.

Arousal. There were no significant results with respect to predicting arousal at t_1, similar to Study 1 (see Table 2 for model summaries, *p*s > .100). Arousal at t_0 was also unrelated to task-unrelated thought (ß = .02), $\chi^2(1) = .224$, $p = .636$, or freely moving thought at t_1 (ß = −.01), $\chi^2(1) = .052$, $p = .820$.

Possible Interaction Effects. Once again, to support our claims of dissociation, we tested the possibility that freely moving thought and task-unrelated thought interacted to influence affect. Models were constructed similar to the ones described in Study 1, where an interaction term was included (Task-Unrelated Thought × Moving Freely moving Thought). Model summaries are available in the online supplemental material.

Similar to Study 1, there were no significant interactions for concurrent valence ($p = .790$) or subsequent valence ($p = .369$), suggesting independent (and not interactive) relationships with valence. We also found no statistically significant relationships with subsequent arousal ($p = .362$). We did, however, find an interaction for concurrent arousal (ß = .05), $\chi^2(1) = 4.10$, $p = .043$. We conducted post hoc simple slopes analyses using the 'interactions' package in R; where the relationship between freely moving thought and arousal was computed at three levels of the task-unrelated thought (one standard deviation below the mean, mean, and one standard deviation above the mean). None of the simple slopes were statistically significant, but it appears that the direction of the relationship differed at values of +1 *SD* and −1 *SD*: Slope for −1 *SD* (less of task): $B = -.05$ ($SE = .03$), $t = -1.48$, $p = .14$; slope for *M*, $B = -.01$ ($SE = .02$), $t = -.27$, $p = .78$; slope for + 1 *SD* (more off-task), $B = .04$ ($SE = .03$), $t = 1.12$, $p = .26$. This is a different qualitative pattern than the results from Study 1, where freely moving thought was positively related to arousal when people reported being on-task (dichotomous response variable). In sum, we did not find reliable direct or interactive effects for arousal across both studies; see General Discussion for more on the lack of replication.

Discussion

Our replication study supported a key finding from Study 1; task-unrelated thought is negatively associated with valence, and freely moving thought is positively associated with valence (see Figure 1). At the same time, we did not find support that freely moving thought is positively associated with arousal, and neither dimension was predictive of subsequent valence or arousal. Study 2 highlights the need for replication and further evidence in the literature while also echoing further doubt on the notion that task-unrelated thought is a direct cause of future unhappiness (see also, Franklin et al., 2013; Poerio et al., 2013; Mason et al., 2013; Ruby et al., 2013).

General Discussion and Conclusion

We provide evidence that task-unrelated thought and freely moving thought are different dimensions of thought with dissociable affective profiles: across two studies, task-unrelated thought was associated with less positive valence than being on-task, whereas freely moving thought was associated with more positive valence (see Figure 1 for nonoverlapping CIs across both studies). The dissociations observed for valence converged with additional exploratory analyses where natural language processing was used to assess the sentiment of the language used to describe streams of thought (Study 1). These findings are the first to demonstrate that freely moving thought does not necessarily have the same functional correlates as task-unrelated thought—specifically that it might have a more positive relationship with affect.

Freely moving thought focuses on the movement in thought over time rather than a specific focus on the content of the thought itself (e.g., task-unrelated thought, or not thinking about the current task). One possibility is that such "free" movement in thought might positively relate to valence since positive affect tends to lead to more flexible, broader thinking (Fredrickson, 2001; Kiken & Fredrickson, 2017). The link between broad thinking and affect might also be bidirectional; generating broad associations can lead to reductions in negative affect and increases in positive affect (Brunyé et al., 2013). In contrast, thoughts that are not moving around might either be deliberately constrained or automatically fixated on a single topic, which might lead to more negative affect (Kircanski et al., 2018; Moberly & Watkins, 2008; Ottaviani et al., 2013). Although it is possible that thoughts are automatically constrained to a single topic like in the case of rumination, freely moving is not simply the opposite of ruminative thinking since thoughts might also be constrained deliberately (i.e., in goal-directed cognition). A limitation of this study is that we did not assess additional dimensions of thought, such as what topic(s) they were thinking about; future work might include these content-based dimensions to tease this relationship apart further.

Task-unrelated thought was related to valence in the opposite direction, which is consistent with previous studies where participants tend to report more positive feelings when they are engaged in a task (Killingsworth & Gilbert, 2010; Wilson et al., 2014). However, we note that in the current study (and others), off-task thinking tends to be more neutral than starkly negative (for more discussion, see Fox et al., 2018; Fox et al., 2014), despite on-task thinking being rated more positively. It is also worth pointing out that task-unrelated thought tends to share a negative relationship with performance and comprehension (Phillips et al., 2016; Randall et al., 2014; Smallwood, 2011), so future work might focus on assessing whether freely moving thought has a similar negative impact on performance, or if it might offer benefits under certain circumstances (i.e., during problem solving, etc.).

Given the importance of replication, it is also important to mention a number of effects that did not replicate across both studies. Freely moving thought was positively associated with concurrent arousal in Study 1, but task-unrelated thought was positively related to arousal in Study 2. These findings might be of interest given that affect is often considered to be a multidimensional construct with two orthogonal dimensions (i.e., valence and arousal; Posner et al., 2005; Russell, 2003; Russell, 1980); yet there has been less focus on the relationship between mind-wandering and arousal in relation to valence. Our exploratory analyses of arousal show that neither dimension of thought was reliably related to arousal in the context of everyday life across both studies. We also found evidence for interactive effects of freely moving thought and task-unrelated thought on arousal, but again the patterns did not replicate across studies. The changes in patterns for arousal across studies highlight the need to explore this dimension more, particularly given that patterns might have changed as a result of the changes in measurement—specifically, that task-unrelated thought explained more variance in arousal once it was measured on a 7-point scaled instead of a dichotomous one (see Seli et al., 2018 for related discussions on measurement issues). The inconsistent pattern of results for task-unrelated thought and arousal (negative, nonsignificant relationship in Study 1; positive, significant relationship in Study 2) also mimics previous inconsistencies observed for physiological arousal, where different directions and strengths of the same relationships have been variable across studies (Franklin, Broadway, et al., 2013; Grandchamp et al., 2014; Robison & Unsworth, 2019; Unsworth & Robison, 2018).

Similarly, freely moving thought only predicted subsequent valence in Study 1, which was not replicated in Study 2. Importantly, neither of our studies replicated the original effect found by Killingsworth and Gilbert (2010); this lack of replication has been reported elsewhere as well (Mason et al., 2013; Poerio et al., 2013; Ruby et al., 2013). Other studies have, instead, found that there are certain conditions when task-unrelated thought might predict subsequent affect: For example, Off-Task + Past-Related thoughts (as determined by principal components analyses) were predictive of more negative valence in the future, while Off-Task + Future-Related thought predicted more positive valence (Ruby et al., 2013) and lower stress reactivity (Engert et al., 2014). These conditional effects of off-task thought suggest that including additional dimensions such as temporality (e.g., Engert et al., 2014; Poerio et al., 2013, etc.), intentionality (e.g., Seli et al., 2016), and level of detail (e.g., Sormaz et al., 2018) will be important for follow up studies. For example, how does freely moving thought predict affect when thoughts are mostly past-related versus future-oriented? Assessing temporality will allow future studies to assess if freely moving thoughts positively relate to subjective valence due to a future-compared with past-focus.

In summary, task-unrelated thought and freely moving thought are both ubiquitous in everyday life, yet freely moving thought has not been a focus of empirical research to date. This might be because task-unrelated thought became a focus of scientific study over a decade ago (Smallwood & Schooler, 2006), whereas freely moving was brought into scientific focus relatively recently (Christoff et al., 2016), with its corresponding experimental measure introduced even more recently (Mills et al., 2018). The almost exclusive focus on task-unrelated thought and its negative role in conditions such as depression and attention-deficit/hyperactivity disorder and its negative impact on learning has painted a rather negative picture of mind-wandering. However, by showing that freely moving thought has a positive relationship with affect, our findings suggest there might be positive aspects of mind-wandering that remain unexplored. Exploring both dimensions in future research promises to enrich our understanding of the multitude of ways in which mind-wandering profoundly influences almost every aspect of everyday life.

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