



Differential relationships between thought dimensions and momentary affect in daily life

R. F. Thiemann¹ · C. Mills² · J. W. Y. Kam^{1,3}

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Abstract

Commonly used to characterize mind wandering, task-unrelated thought has long been associated with negative affective outcomes. However, less is known about how other thought dimensions including intentionality and freedom of movement interact with task-unrelated thought to modulate momentary affect in everyday life. To address this, we used ecological momentary assessments to prompt participants to report their thought patterns and affective valence five times a day for seven consecutive days. Each assessment asked participants to report on their affective valence as well as several thought dimensions including their task-relatedness, intentionality and freedom of movement. We examined the latter two thought dimensions alone as well as how they interacted with the commonly examined dimension of task-relatedness with respect to their relationship to momentary affect. We replicated the well-established negative relationship between task-unrelated thought and momentary affect. Furthermore, unintentional task-unrelated thought was associated with more negative affect than intentional thought. This pattern was also observed more broadly in thoughts regardless of their task relevance. In contrast, freely moving thought was positively related to momentary affect in general. A significant interaction between task-relatedness and freedom of movement of thought revealed that the commonly reported negative relationship between task-unrelated thought and more negative affect is mitigated by freely moving thought. In summary, our findings indicate that these various thought dimensions have unique relationships with momentary affect, highlighting the importance of accounting for thought dimensions in establishing its affective and possibly other functional consequences.

Introduction

A common occurrence in everyday life involves engaging in a panoply of thoughts encompassing a variety of content that unfold in different ways over time (Mckeown et al., 2021; Mills et al., 2018; Poerio et al., 2013). Examined in the context of mind wandering, this work has revealed wide ranging detrimental consequences in task performance and

affective well-being on one hand (Mooneyham & Schooler, 2013) and positive outcomes in creative problem solving and future planning on the other (McMillan et al., 2013); though findings on the relationship between mind wandering and creativity have been mixed (Smeekens & Kane, 2016; Steindorf et al., 2021; Zedelius et al., 2021). Many of these studies have conceptualized mind wandering as task-unrelated thought, which is characterized by a shift in the focus of thoughts away from the ongoing task (Smallwood & Schooler, 2006, 2015). Estimated to occupy up to half of our waking hours (Kane et al., 2007; Klinger & Cox, 1987), task-unrelated thought is commonly linked to increased negative affect or reduced psychological well-being (Carciofo et al., 2014; Choi et al., 2017; Hobbiss et al., 2019; Killingsworth & Gilbert, 2010). Given the growing recognition of the complex and heterogeneous nature of these thoughts (Christoff et al., 2016; Seli et al., 2016; Stawarczyk, 2018), a more nuanced characterization of this phenomenon is necessary when determining its impact. To that end, while earlier studies focused on the content of task-unrelated thought (Franklin et al., 2013; Poerio et al., 2013; Ruby

✉ J. W. Y. Kam
julia.kam@ucalgary.ca

R. F. Thiemann
raela.thiemann@ucalgary.ca

C. Mills
cmills@umn.edu

¹ Department of Psychology, University of Calgary, 2500 University Dr. NW., Calgary, AB T2N 1N4, Canada

² Department of Educational Psychology, University of Minnesota, Minneapolis, MN 55415, USA

³ Hotchkiss Brain Institute, University of Calgary, 3330 Hospital Dr. NW., Calgary, AB T2N 4N1, Canada

et al., 2013), recent work has suggested that other dimensions of thought such as the intentionality and freedom of movement of thought are differentially associated with affective well-being (Mills et al., 2021; Seli et al., 2019). Considering the prevalence and variety of these thoughts and the value our society places in improving well-being, a more comprehensive examination of the differential relationship between thought types and affective well-being is necessary. Accordingly, the present study aims to establish the nature of the relationship between different dimensions of thought and momentary affective states.

Relationship between task-relatedness of thought and affective well-being: Thought Content

Ample research has converged on the robust association between task-unrelated thought and worsened affect and well-being. The majority of these studies have assessed both constructs in terms of their tendencies or trait-level characteristics using questionnaires, suggesting that individuals who engage in more frequent episodes of task-unrelated thought are more likely to report lower psychological well-being (Carciofo & Jiang, 2021; Marchetti et al., 2014; Seli et al., 2019). Notably, studies using ecological momentary assessment (EMA) have revealed more mixed findings. In contrast to questionnaires, EMA can capture daily fluctuations in thought and affective patterns within and across individuals by assessing their momentary experience via short surveys throughout the day (Shiffman et al., 2008). The initial study using EMA has reported lower levels of happiness during bouts of task-unrelated thoughts compared to on-task thoughts (Killingsworth & Gilbert, 2010), leading to the conclusion that “a wandering mind is an unhappy mind.” Although this study is corroborated by a few subsequent studies using the same methodological approach (Arch et al., 2021; Choi et al., 2017; Franklin et al., 2013), others have failed to replicate this finding (Welz et al., 2018) or found this to be true only if their thoughts were not interesting (Franklin et al., 2013) or about the past and other individuals (Ruby et al., 2013), or the content of those thoughts were negative (Poerio et al., 2013). In fact, when these thoughts were considered interesting, it was linked to more positive affect compared to task-related thoughts (Franklin et al., 2013). These findings support the content regulation hypothesis (Smallwood & Andrews-Hanna, 2013), which purports that the content (rather than the occurrence) of task-unrelated thought modulates its consequences on our daily life. It is perhaps not surprising then that the majority of studies that have introduced nuances in the relationship between task-unrelated thought and affect have focused on how this relationship changes as a function of thought content.

Content alone, however, may not capture how thoughts arise and unfold in manners that facilitate changes in affect.

Here, we focus on two thought dimensions that specifically address this: (1) whether thoughts are initiated intentionally or unintentionally and (2) if they are freely moving (i.e., unguided) over time. There is ample reason to believe both of these dimensions may be related to affective well-being (Mills et al., 2021; Seli et al., 2019). We provide the first systematic test of how they may modulate the relationship between task-unrelated thought and affect in everyday life contexts.

Intentionality of thought and its association with affective well-being: Thought Initiation

One relevant dimension of thought concerns whether it occurs with or without intention. To date, this dimension of thought has predominantly been studied in the context of task-unrelated thought (Carriere et al., 2013; Giambra, 1995; Seli et al., 2016), where it is considered to initiate either with or without intention (Seli et al., 2016). Intentional and unintentional task-unrelated thought have dissociable functional correlates (including the content, frequency and temporal focus of thoughts; Seli et al., 2016, 2017) and consequences (including emotional dysfunction; Seli et al., 2019), highlighting the importance of distinguishing whether task-unrelated thought is intentionally or unintentionally engaged. In particular, unintentional task-unrelated thought has stronger positive relationships with anxiety and negative affect compared to intentional task-unrelated thought (Carciofo & Jiang, 2021; Seli et al., 2019), suggesting unintentional task-unrelated thought is more detrimental to affective well-being than intentional task-unrelated thought.

Thus far, this relationship has mostly been studied at the trait level assessed via questionnaires (e.g., Seli et al., 2016) or via experience sampling in a laboratory (e.g., Kruger et al., 2020, 2021); a question that follows from these findings is whether the intentionality of task-unrelated thought is associated with momentary affect in everyday life as well. Considering these results beyond the context of task-unrelated thought, it is also possible that the intentionality of task-related thoughts, or thoughts broadly speaking regardless of task relevance, may have differential relationships with momentary affect. This question of whether unintentionally versus intentionally engaged thoughts in general are related to different levels of momentary affect in the real world remains unknown. What has also been unexplored is whether this effect of intentionality interacts with task-relatedness in modulating momentary affect. Based on previous work implicating unintentional thoughts (characterized by lack of control and not requiring any effort) in mentally distressing rumination (Shigemoto et al., 2017) as well as depression and anxiety (Yapan et al., 2020), we predict that we will observe a main effect of intentionality, such that unintentional thoughts will be related to more negative

momentary affect than intentional thoughts. Further, given that questionnaire-based research has found a stronger link between affective dysfunction and unintentional compared to intentional task-unrelated thought (Seli et al., 2019), we also hypothesize an interaction between intentionality and task-relatedness, such that unintentional task-unrelated thought will be more strongly associated with negative affect than intentional task-unrelated thought.

Freedom of movement in thought and its relation to momentary affect: Thought Dynamics

Another thought dimension that may also serve as an important factor in determining affect is the freedom of movement of thought. One framework suggests freely moving thought better aligns with the connotations of mind “wandering” (Christoff et al., 2016), which characterizes mind wandering as thoughts that wander freely with minimal constraints (Irving, 2016). Although correlated with task-unrelated thought, this freely moving dimension has been shown to be dissociable from task-relatedness: freely moving thoughts can co-occur with thoughts that are task-related (e.g., a musician brainstorming ideas for a new melody) and task-unrelated (e.g., a student jumping from thoughts about movies to vacation spots while studying; Mills et al., 2018). These two dimensions are also associated with unique affective outcomes. Specifically, while task-unrelated thoughts have been associated with more negative affect, freely moving thought was linked to more positive affect (Mills et al., 2021). This pattern replicated across two studies; however, there was no interaction effect between these two thought dimensions on affective valence. Based on these findings, we predict that freely moving thought will predict higher levels of positive affect compared to thoughts that are not freely moving regardless of task relevance, and that task-relatedness will not interact with freedom of movement of thought in predicting momentary affect.

The Present Study

Together, these lines of research converge on the notion that distinct dimensions of thought can be differentially associated with momentary affect, suggesting that the dominant narrative of a relationship between mind wandering commonly conceptualized as task-unrelated thought and negative affect may not apply broadly to different thought dimensions and characterizations of the phenomenon. Moving beyond the content regulation hypothesis that places emphasis on thought content (Andrews-Hanna et al., 2014; Smallwood & Andrews-Hanna, 2013), these findings highlight the importance of accounting for the nature and form of thought as captured by these thought dimensions in examining their functional consequences. The current study thus examined

the relationship between the aforementioned thought dimensions, namely task-relatedness of thought, intentionality of thought and freedom of movement of thought, and momentary affect in everyday life. Using ecological momentary assessments, we asked participants to report on their thought patterns and affect through five daily surveys for seven consecutive days. This approach afforded the opportunity to examine the transient changes in our thoughts and affect over the course of a day (Shiffman et al., 2008).

Methods

Participants

A total of 143 participants completed this study (gender: 114 female, 21 male, 1 preferred not to report, 3 non-binary, 4 unspecified; age: mean = 19.84, SD = 1.94, range = 17–32). Most participants were White (28.7%) or Asian (27.3%); other ethnicities and responses reported were Hispanic (2.8%), African American (0.7%), Indigenous (0.7%), Pacific Islander (0.7%), multiracial (7.7%), other (9.8%), or not reported (21.7%). Given past studies examining similar questions (e.g., Choi et al., 2017; Mills et al., 2021) reported small-medium effect sizes, we set relatively conservative estimates of a smaller effect size ($f^2 = 0.07$; based on canonical effect sizes for Cohen's f^2 : small = 0.02, medium = 0.15) as some of our aims are novel. Based on a critical alpha of 0.05, two tailed, we used G*Power 3.1 (Faul et al., 2009) to determine that the sample size needed to obtain 80% power in a linear regression to detect an effect size of $f^2 = 0.07$ is $N = 115$. We recruited additional participants in anticipation of attrition and non-compliance rates based on past EMA studies (Kam et al., 2021; Mills et al., 2021). They were recruited via participation in another larger study examining a different research question regarding the COVID-19 pandemic; participants who expressed interest in the current study were recruited. This study was approved by the University of Calgary Conjoint Faculties Research Ethics Board (REB21-0542). All participants provided informed consent, and they either received course credits or were entered into a lottery to win one of two \$50 e-gift cards for their participation.

Ecological Momentary Assessments

We used ecological momentary assessments (EMA) to assess both momentary thought dimensions and affective valence. This approach enabled us to capture one's ongoing experience throughout the day in a naturalistic setting without concerns for retrospective bias or memory inaccuracies (Shiffman et al., 2008). Participants received five EMA every day for 7 days, for a total of 35 surveys.

They were sent via email through the Qualtrics platform at randomized times within a 10-h time window specified by the participant, and each survey was sent at least 30 min apart. Participants were asked to complete the survey within 15 min of receiving the email notification. Prior to the start of the study, participants were reminded to turn on their email notification on their phone so they would be alerted to each survey and could respond to the surveys within the specified time window. They were instructed to report their ongoing experience just before they received the notification.

Each survey consisted of the same set of questions. To assess the relationship between different thought types and momentary affect, we asked participants to rate their affect and report the extent to which their thoughts were task-unrelated, intentional and freely moving. To control for the effects of salient or unusual external events that may modulate this relationship, we also asked participants to report the presence and valence of any salient events that occurred prior to the survey. The following questions and response options were presented at each survey: (1) How on-task or off-task were your thoughts? Rated on a scale from 1 (*completely on-task*) to 7 (*completely off-task*); (2) To what extent were your thoughts freely moving or not within the past minute or so? This question assessed the freedom of movement in participants' thoughts, and was rated on a scale from 1 (*not at all*) to 7 (*extremely*); (3) Did you unintentionally or intentionally engage in what you were doing or thinking about? Response options were *intentionally* or *unintentionally*; (4) How positive or negative do you feel at this moment? Rated on a scale from 1 (*extremely negative*) to 7 (*extremely positive*); (5) Have any salient positive or negative events happened in your life since the last survey? Response options included *no*, *yes—positive*, and *yes—negative*. Additional questions asked at each survey (as reported in Supplementary Table 1) were not relevant to our research question and thus not included in subsequent analyses.

A total of 4104 survey responses were collected in total, resulting in 82.0% average EMA survey completion rate. Individual survey responses were excluded if they took more than five minutes to complete (i.e., exclusion of 35 responses, 0.9% of total survey response) or if they were completed more than 30 min after the survey was sent (1000 responses, 24.3%), suggesting that their responses may no longer capture the experiences just prior to the survey (Kam et al., 2021). Participants were also excluded if they responded to less than 30% of EMA surveys (i.e., exclusion of 30 participants, 21% of sample; Mills et al., 2021; Shackman et al., 2018; Takano et al., 2013), suggesting they were not engaged in the study or did not follow instructions. The final sample for the EMA data contained 2883 survey responses from 113 participants, which was sufficient to detect small-medium effects (gender: 91 female, 17 male,

1 preferred not to report, 3 non-binary, 1 unspecified; age: mean = 19.93, SD = 2.09, range = 17–32).

Procedure

This study was conducted via the online platform Qualtrics Inc. (2020). One day prior to the start of the study, participants were asked to go over an information package (as described in Supplementary Materials) via Qualtrics. This consisted of a detailed description of each question in the EMA surveys and a description of the response options along with example scenarios. In addition, participants were given an example scenario that they may find themselves in during the study and asked to respond to the EMA survey based on the scenario. These extensive explanations and practice of completing the survey served two purposes: it ensured that participants understood the meaning of the questions asked of them at each survey as well as how to respond to them and it familiarized the participants with the questions and the survey layout. Upon completion of this exercise, EMA surveys were scheduled to begin the next day lasting seven days. Participants received a check-in email half-way through the study that gave them another opportunity to clarify their questions and served the purpose of encouraging them to complete the study.

Analysis

We implemented several sets of analyses to determine whether thought dimensions differentially associated with momentary affect, and to what extent salient external events modulated this relationship. All fixed effect variables were standardized prior to analysis. In general, we implemented hierarchical linear regression analyses with mixed models and used Chi-squared analyses to compare log-likelihood statistics for determining statistical significance of models.

We examined the relationship between different dimensions of thoughts and momentary affect by focusing on several thought dimensions: task-relatedness of thought, intentionality of thought, and freedom of movement of thought. Prior to analysis, given past studies have reported weak correlations between some of these variables (Mills et al., 2018, 2021), we examined the extent to which these variables were correlated with each other to test for multicollinearity. Specifically, we implemented linear regression analyses with mixed models, and based on these results computed the R^2 value to examine the amount of variance in one variable that can be accounted for by the other. We adopted a conservative threshold of $R^2 = 0.6$, above which multicollinearity is considered too severe for variables of interest to be included in the same model (Mills et al., 2021). Accordingly, the results of these control analyses would indicate whether our independent variables can be included in the same model.

To examine the relationship between task-relatedness of thoughts and momentary affect, the base regression model included a random intercept effect of participants, and task-relatedness as the fixed effect independent variable of interest assessed via EMA surveys. Based on past findings of stronger associations between unintentional task-unrelated thoughts and worsened well-being as assessed via questionnaires, we then determined whether the relationship between task-unrelated thought and momentary affect was modulated by intentionality of thoughts. To test this, we added a fixed effect of intentionality to the base model and examined whether an interaction between intentionality and task-unrelatedness further improved model fit. If the interaction model improved model fit, we selected this model as it best represented the data. To clarify an interaction effect, we then used simple effects analyses to examine how task-unrelated thought differentially related to momentary affect depending on whether participants intentionally engaged in them.

In a second set of regression analyses with the same base model, we then added a fixed effect of freedom of movement in thought and examined whether an interaction between freedom of movement and task-relatedness further improved model fit. In addition to main effects of these two thought dimensions, we used simple effects analyses to examine how the relationship between task-unrelated thought and momentary affect changes as a function of whether or not these thoughts were freely moving (i.e., comparing responses to this thought dimension that are one standard deviation above and below the mean).

As control analyses, we examined whether these relationships between thought dimensions and momentary affect can be accounted for by salient external events. For instance, a major event in life (e.g., loss of a loved one or missed job opportunity) may be a third variable that significantly impacts one's thought patterns and momentary affect. Therefore, accounting for such influence is crucial in revealing the underlying relationship between thought dimensions and momentary affect. To control for this, we obtained reports of any salient events that occurred prior to each EMA survey as well as the valence of those events (i.e., positive, negative, neutral). In order to ensure that the relationships between thought dimensions and affect were not an epiphenomenon of salient external events, the aforementioned linear regression models were implemented with an additional variable of saliency of external events as a fixed effect along with the other variables in the model.

All analyses were performed using R (version 3.6.2; R Core Team, 2019) in R Studio (version 2019.12.03; RStudio Team, 2020) and the following packages: plyr, dplyr, and tidyr, to organize the data; lme4, lmerTest, car, and sjPlot, for modeling and model evaluation; emmeans and effectsz, for simple effects analysis; and ggplot2, for creating figures.

Results

Relationship between types of thought

Participants reported engaging in task-unrelated thought on average 31.03% (SD = 20.15%) of the time, in intentional thoughts on average 54.22% (SD = 22.19%) of the time, and in freely moving thought on average 30.59% (SD = 19.60%) of the time. Descriptive statistics and correlations between relevant variables are reported in Supplementary Table 2. Given past work has reported a positive relationship between task-unrelated and freely moving thought (with β ranging from 0.229–0.246; Mills et al., 2018, 2021), we examined the extent to which they are associated with each other using mixed effects linear regression in the current data set. The task-relatedness dimension was positively related to the intentionality dimension ($p < 0.001$) and freely moving dimension ($p < 0.001$). Specifically, the task-relatedness dimension accounted for similar variance in both of these dimensions (intentionality, $R^2 = 0.339$; freely moving, $R^2 = 0.337$). As these values fell below the conservative threshold of $R^2 = 0.60$ for determining multicollinearity between predictors, the task-relatedness variable along with each of these variables were included as predictors in separate, planned models in predicting momentary affect.

Relationships between thought type and momentary affect

Separate mixed effects linear regression models were implemented to determine whether the relationship between task-unrelated thought and momentary affect is moderated by different dimensions of thoughts and their interactions with task-relatedness of thought. Age and gender (coded as 1 = female and 2 = male) did not significantly predict momentary affect (age: $b = 0.0008$, $SE = 0.04$, 95% CI = $[-0.07, 0.07]$, $p = 0.981$; gender: $b = 0.03$, $SE = 0.21$, 95% CI = $[-0.38, 0.44]$, $p = 0.889$), and the inclusion of age and gender in the models did not change the pattern of results in any of the following analyses. We, therefore, reported the results of models without these two covariates in the interest of brevity.

First, we examined whether task-relatedness of thought along with intentionality of thought predicted momentary affect. Table 1 reports the results of these regression analyses. The task-relatedness of thought negatively predicted momentary affective valence ($p < 0.001$), such that the more thoughts were task-unrelated, the lower the reported affect. The intentionality of thought also predicted the valence of momentary affect ($p < 0.001$), with thoughts

Table 1 A linear mixed effects regression model of task-relatedness and intentionality of thought predicting momentary affect

IV ^a	β^b	SE ^c	95% CI ^c	$\chi^2(1)^d$	p^d
TR	-0.20	0.03	[-0.27, -0.13]	37.31	<0.001
Intent	0.25	0.05	[0.16, 0.35]	28.69	<0.001
TR × Intent	0.11	0.05	[0.02, 0.20]	5.54	0.019
TR at intent	-0.09	0.03	[-0.15, -0.03]	8.37	0.004
TR at unintent	-0.20	0.04	[-0.27, -0.13]	31.23	<0.001

The first three rows present the three independent variables' effects on the dependent variable of momentary affect (ranging from 1=extremely negative to 7=extremely positive). The three fixed effects independent variables included task-relatedness (TR; ranging from 1=completely on-task to 7=completely off-task), intentionality (coded as unintentional (reference value) or intentional), and their interaction (TR × Intent). The last two rows present results from two linear mixed effects regression models that follows up on the significant TR × Intent interaction effect, testing the effect of task-relatedness on affect separately implemented for thoughts that are intentionally engaged (Intent) and unintentionally engaged (Unintent)

^aIV = independent variables

^b β = standardized coefficient

^cSE = standard error of the mean and 95% CI = confidence interval, associated with the standardized coefficient

^d p -value associated with the χ^2 -statistic, which tests the current model against a null model without the independent variable of interest

that were unintentionally engaged (regardless of task-relatedness) being associated with more negative affect.

Notably, there was a significant interaction between these two thought dimensions ($p=0.019$). To follow-up on this interaction, we implemented two analyses examining whether task-relatedness of thought differentially predicted momentary affect during intentional thoughts and unintentional thoughts. These post hoc analyses revealed that the task-relatedness of thought predicted affect during thoughts that were intentionally engaged ($p=0.004$), as well as thoughts that were unintentionally engaged ($p<0.001$). Both sets of results suggest that task-unrelated thought was associated with more negative affect when they were unintentionally and intentionally engaged; however, the magnitude of this relationship is more than two times greater during unintentionally ($b=-0.20$) compared to intentionally ($b=-0.09$) engaged task-unrelated thought.

We then tested how task-relatedness of thought and freely moving thought differentially predicted momentary affect. Table 2 reports the results of these regression analyses. As with the above analyses, the task-relatedness of thought was linked to more negative momentary affect ($p<0.001$). In contrast, the freedom of movement of thought was positively associated with momentary affective valence ($p<0.001$); specifically, thoughts that were more freely moving were associated with more positive affect, replicating previous work (Mills et al., 2021).

Table 2 A linear mixed effects regression model of task-relatedness and freedom of movement thought dimension predicting momentary affect

IV ^a	β^b	SE ^c	95% CI ^c	$\chi^2(1)^d$	p^d
TR	-0.26	0.03	[-0.31, -0.21]	99.38	<0.001
FM	0.10	0.03	[0.05, 0.15]	17.32	<0.001
TR × FM	0.04	0.02	[0.001, 0.08]	3.97	0.046
TR at non-FM	-0.28	0.07	[-0.41, -0.14]	16.19	<0.001
TR at FM	-0.09	0.06	[-0.22, 0.04]	1.97	0.160

The first three rows present the three independent variables' effects on the dependent variable of momentary affect (ranging from 1=extremely negative to 7=extremely positive). The three fixed effects independent variables included task-relatedness (TR; ranging from 1=completely on-task to 7=completely off-task), freedom of movement (FM; ranging from 1=not at all freely moving to 7=extremely freely moving), and their interaction (TR × FM). The last two rows present results from two linear mixed effects regression models that follows up on the significant TR × FM interaction effect, testing the effect of task-relatedness on affect separately implemented for thoughts that are not freely moving (non-FM; below 4 on the scale) and freely moving (FM; above 4 on the scale)

^aIV = independent variables

^b β = standardized coefficient

^cSE = standard error of the mean and 95% CI = confidence interval, associated with the standardized coefficient

^d p -value associated with the χ^2 -statistic, which tests the current model against a null model without the independent variable of interest

Notably, however, there was also a significant interaction between these two dimensions of thoughts ($p=0.047$). To follow-up on this interaction, we implemented two separate analyses examining the impact of task-relatedness of thought on momentary affect during freely moving thought and non-freely moving thought (as indexed by responses one standard deviation above and below the mean, respectively). These post hoc analyses revealed a significant effect of task-relatedness of thought on affect during thoughts that were not freely moving ($p<0.001$), indicating task-unrelated thought was negatively related to affect. However, this was not significant during freely moving thought ($p=0.161$), indicating that task-relatedness of thought is not related to affect when thoughts are freely moving from one topic to another. This suggests that freely moving thought mitigates the negative relationship between task-unrelated thought and affect.

Controlling for the influence of salient external events

To account for the impact of salient external events on the relationship between thought dimensions and momentary affect, we included a covariate of saliency in all the aforementioned regression models. The saliency variable was significant in all included models (p 's < 0.001), such

that positive salient events were associated with enhanced momentary affect compared to the absence of salient events that occurred prior to the survey, and negative salient events were associated with reduced affect compared to no salient events. The patterns of results regarding the link between thought dimensions and affect were identical to models without this covariate, suggesting although saliency of external events predicted momentary affect, it did not account for the relationship between thought dimensions and affective valence. These analyses are reported in Supplementary Table 3.

Discussion

In this study, we examined the relationship between several thought dimensions and momentary affect. This included not only the task-relatedness of thought, but also the intentionality and freely moving thought dimensions and their interaction with task-relatedness. We replicated the well-established negative relationship between task-unrelated thought and momentary affect. Similar to past questionnaire-based findings, unintentional task-unrelated thought was associated with more negative momentary affect than intentional task-unrelated thought. This pattern was also observed more broadly in thoughts in general regardless of their task relevance. In contrast, freely moving thought was positively related to momentary affect in general. Moreover, only task-unrelated thought that was not freely moving was linked to negative affect, whereas for freely moving thought, task-relatedness did not predict affect. Taken together, these findings indicate that these various thought dimensions have unique and opposing relationships with momentary affect, highlighting the importance of considering the nature of thoughts in establishing its functional implications.

Task-unrelated thought negatively predicts affect

Consistent with the dominant narrative, we found that task-unrelated thought was associated with more negative affect. This is a well-established finding that has been reported by studies mainly using questionnaires (Carciofo & Jiang, 2021; Johannes et al., 2018; Seli et al., 2019). Among those that used ecological momentary assessments, the findings are somewhat mixed. Indeed, several studies using EMA have reported this common finding of a negative relationship between task-unrelated thought and affect (Arch et al., 2021; Choi et al., 2017; Franklin et al., 2013; Killingsworth & Gilbert, 2010). However, in other cases, task-unrelated thought has predicted more positive affect both in general (Welz et al., 2018) and when these thoughts were rated as interesting (Franklin et al., 2013) and positively focused on the self and the future (Ruby et al., 2013). That the

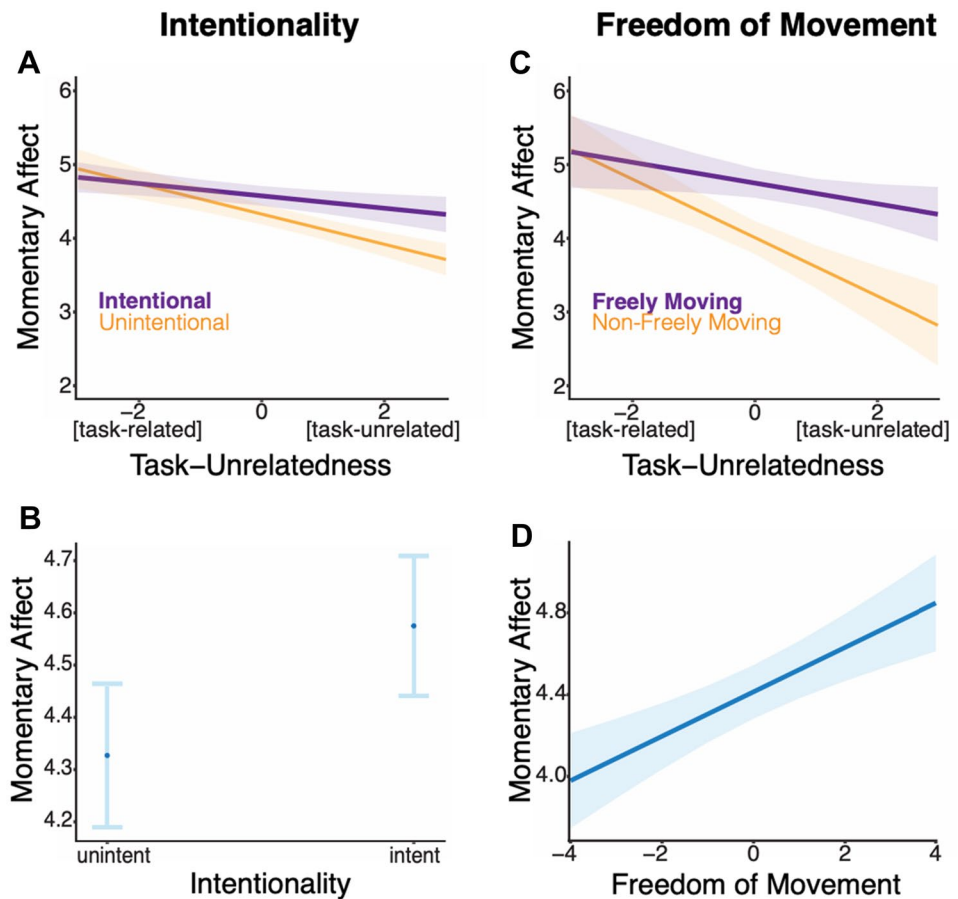
robustness of this finding varies as a function of methodology is hardly surprising given what these measures capture: while questionnaires assess the overall tendencies or traits of the measured construct, EMA provides a glimpse of one's experience in the moment (Shiffman et al., 2008). For example, a person who scores high on trait-level negative affect may still experience more positive affect every time they have a particular type of thought. Using a broad definition (i.e., task-unrelated thought) that overlooks other content or dimensions of thought combined with EMA data focusing on concurrent affect, our findings corroborate the established finding that task-unrelated thought was linked to more negative momentary affect. This indicates less positive ratings of affect when thinking about topics that are unrelated to the current task compared to task-relevant topics. Notably, however, the magnitude of this relationship with momentary affect changes as we consider other thought dimensions and their interaction with task-unrelated thought—particularly using dimensions that do not focus on content alone.

Intentionality of thought modulates momentary affect

We found that the intentionality of thought modulates the magnitude of its relationship with momentary affect, supporting our hypothesis. Previous studies have reported that unintentional task-unrelated thought was associated with more negative psychological well-being relative to intentional task-unrelated thought (Carciofo & Jiang, 2021; Seli et al., 2019). As these past studies have all used questionnaires or experience sampling in a laboratory setting to assess intentionality, our study is the first to our knowledge to reveal that unintentional task-unrelated thought predicted higher levels of negative momentary affect compared to intentional task-unrelated thought in everyday life. The effect size for unintentional task-unrelated thought was more than twice the size of that for intentional task-related thought, suggesting that unintentional task-unrelated thoughts exacerbate the affective outcome. Notably, even when thoughts were task-unrelated, the predicted affective valence of thoughts that were intentionally engaged fell within the positive affect range (i.e., scores of above 4 on the 7-point affective valence scale, as shown in Fig. 1). In other words, although there is a negative relationship between task-unrelated thought and affect, task-unrelated thought engaged with intention predicts positive momentary affect, suggesting that task-unrelated thought may not always be linked to negative affect.

This effect of intentionality applied to thoughts broadly; that is, unintentional compared to intentional thought was linked to more negative affect regardless of whether or not those thoughts were related to the ongoing task. While past studies have only examined the intentionality of task-unrelated

Fig. 1 Thought dimensions predicting momentary affect. **A** Task-unrelated thought predicted more negative affect than task-related thought when they were unintentional and intentional, however the effect was stronger for unintentionally engaged thoughts. **B** Intentional thoughts were linked to more positive momentary affect than unintentional thoughts, regardless of task relevance. **C** Task-unrelated thought predicted more negative affect than task-related thought for thoughts that were not freely moving, but this effect was mitigated by freely moving thoughts. **D** Freely moving thoughts were positively linked to momentary affect, regardless of task relevance



thought, this novel finding suggests that having a sense of control over the focus of our thoughts in general increases our affective valence in the moment. Previous studies have suggested that this effect in the context of task-unrelated thought may be explained by attentional failure, which characterizes both unintentional task-unrelated thoughts (McVay & Kane, 2009; Seli et al., 2016) and psychological distress (Eysenck & Derakshan, 2011; Shi et al., 2019). This potential explanation may apply more broadly to thoughts in general; that is, a failure to control the focus of our attention and thoughts regardless of their task relevance results in negative affective outcomes. In particular, past studies have implicated attentional dysfunction in depressive symptoms (Strauman, 1999), whereas improving attentional control has been shown to alleviate those symptoms possibly through an increased ability to self-regulate (Rueda et al., 2004). Accordingly, a sense of control over the thoughts we engage in may lead to enhanced capacity for self-regulation which has positive implications for momentary affect.

Freely moving thought is associated with more positive affect

Freely moving thought was associated with more positive momentary affect. The relationship between freedom of

movement in thought and affective valence aligns with previous research (Mills et al., 2021) and supports our hypothesis. An explanation for this finding is the broaden-and-build theory, which proposed that the broadening of attentional focus and other cognitive processes is linked to increased positive affect (Fredrickson, 1998, 2001). This theory may explain how freely moving thought, which is characterized by the shifting between a breadth of topics and mental states, predicts more positive affect.

In contrast to past work (Mills et al., 2021) and thus our hypothesis, however, we found that freedom of movement interacted with task-relatedness in predicting affect. Specifically, task-unrelated thought predicted more negative affect, but only when thoughts were not freely moving (and thus more confined to a single topic). The effect of task-relatedness on momentary affect was not significant when thoughts were more freely moving. This pair of findings suggests that only when thoughts are confined to a particular topic do their task relevance negatively predict affective valence—possibly due to a form of constraint that narrows the focus of thoughts. Indeed, a narrower focus is often considered to be a product of negative affect in previous emotion induction studies (Fredrickson & Branigan, 2005; Gable et al., 2015). The benefits of broadening and shifting between mental

states (Fredrickson, 1998, 2001) may thus mitigate the commonly reported negative relationship between task-unrelated thought and affective valence, and specifically highlights a condition under which task-unrelated thought does not influence momentary affect. One potential reason for the discrepancy in this interaction effect between our study and a previous study (Mills et al., 2021) reporting no interaction may concern the amount of variance in freely moving thought that is explained by task-unrelated thought (i.e., 26% in our study and 10% in Mills et al., 2021). Another possible explanation is that our study had numerically lower rates of task-unrelated thought in general (i.e., 31% here compared to over 50% in Mills et al., 2021). Moving forward, we may need to consider both the occurrence rate and relationships between the occurrence of thought dimensions when examining their interaction effect on affective valence.

The implications of these findings are twofold. First, although task-unrelated thought and freely moving thought are weakly correlated here and in past studies (Mills et al., 2018, 2021; O'Neill et al., 2021), they have distinct and opposing affective outcomes. Second, task-unrelated thought need not always be associated with more negative affect; under certain conditions wherein thoughts are freely moving, task-relatedness of thought did not predict momentary affect.

Saliency of external events

Another novel finding of our study is that the saliency of external events also predicted momentary affect. Not surprisingly, positive salient events were linked to increased momentary affect whereas negative events were linked to reduced momentary affect. Our pattern of results involving thought dimensions and momentary affect remained the same even after the saliency of external events was accounted for in the models. Although this suggests that the relationship between thought dimensions and affect cannot be explained by salient external events, the valence of these events does correspond to momentary affective valence. This finding emphasizes the importance of considering external factors related to both our thoughts and momentary affect when examining their relationship. In particular, future studies should consider examining the interactions between external factors (such as the presence and valence of salient events) and internal factors (thought dimensions) in predicting momentary affect.

Limitations and Conclusion

Several limitations in the present study should be considered. First, there is a disproportionate percentage of females (82%) in our sample. This is particularly notable given gender differences have been reported in psychological

symptoms (Afifi, 2007; Gao et al., 2020; Otten et al., 2021). Importantly, we did control for gender by including it as a covariate in our analyses to ensure that gender alone could not explain our results. We found that gender did not significantly predict momentary affect in most models, and that the overall patterns of results remained the same with and without gender included in the regression model. Two related considerations concern the demographic composition of our sample: (1) we did not control for the impact of sub-clinical or clinical symptoms of mood disorder on the reported relationships; (2) our sample is composed of individuals from W.E.I.R.D. (Western, educated, industrialized, rich, and democratic) societies (Henrich et al., 2010), thereby limiting the generalizability of our findings. Future research needs to consider different demographic characteristics to assess whether our findings apply to a broader population. Second, we only assessed affective valence but not affective arousal, which has been shown to have a differential relationship with different thought dimensions (Mills et al., 2021; Miś & Kowalczyk, 2020; Poerio et al., 2015). Future investigations of the relationship between different thought dimensions and affect should include measurements of both affective valence and arousal to provide a thorough characterization of this relationship. Lastly, given that we allow participants to respond some time after they receive the survey prompt, we cannot be certain that retrospective bias did not influence their response despite our best attempt to limit this possibility. Although it is common to ask participants to respond to the surveys within a specified time window (e.g., 15–30 min) of receiving them (Kuehner et al., 2017; Welz et al., 2018) as it may be unsafe to respond immediately, this time window creates an opportunity for retrospective bias if participants do not respond right away. As this limitation is common for studies that use the EMA method, future large-scale investigations acquiring sufficient data points may examine these relationships only in responses provided immediately upon receiving the survey.

In summary, our study revealed unique relationships between momentary affect and several thought dimensions, highlighting their distinct affective outcomes. These findings uncovered conditions in which mind wandering often characterized as task-unrelated thought does not result in negative affect, suggesting a more nuanced relationship between thoughts and affective well-being than commonly assumed. In fact, freely moving, task-unrelated thoughts as well as freely moving and intentional thoughts in general can even be associated with positive affect. Accordingly, beyond thought content (Andrews-Hanna et al., 2014; Smallwood & Andrews-Hanna, 2013), these findings underscore the importance of accounting for the nature of our thoughts when considering their functional consequences. Only in acknowledging the diverse conceptualizations of mind wandering and thoughts in general can future research work

towards a comprehensive mapping of the dissociable affective, psychological and cognitive outcomes of thought.

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Author contributions RFT and JWYK contributed to study conceptualization and design. RFT contributed to data collection and administration of measurements and prepared all tables and figures. JWYK contributed to data analysis. RFT, JWYK, and CM collaboratively wrote and edited the manuscript, and contributed to data interpretation. All the authors read and agreed on the final manuscript.

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Data availability statement The datasets collected and analyzed during the present study are available on the OSF platform, and can be found here: <https://osf.io/fwnzs/>.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethics approval This study was approved by the University of Calgary Conjoint Faculties Research Ethics Board (REB21-0542).

Consent to participate Informed consent was obtained from all individual participants included in the study.

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