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Local use-dependent activity triggers mind wandering: resource depletion or executive dysfunction?

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Abstract

Mind wandering (MW) is a highly prevalent phenomenon despite its negative consequences on behaviour. Current views about its origin share the idea that MW occurs due to changes in the executive functions system. Here, we argue that not all instances of MW are necessarily related to changes in that system. Combining results from MW and sleep research, we propose that MW could also be related to the depletion of resources in primary task-related networks. To test this hypothesis, participants performed four sessions of the texture discrimination task (TDT) on a day. The TDT is a perceptual learning task in which performance is negatively related to the local build-up of sleep pressure. During the TDT, MW was recorded in both a subjective (i.e., with thought probes) and an objective (i.e., phasic pupillary response) manner. Results showed that accuracy on the TDT was mirrored in the objective measure of MW. For the subjective measure, the pattern was similar to that of task performance but could not be interpreted as reliable. These results demonstrate that not all MW is necessarily related to changes in the executive system and support the hypothesis that MW could be related to the depletion of local, task-related resources.

Keywords: mind wandering, executive system, resource depletion, phasic response, thought probe.

Public significant statement: Our study contributes to the ongoing debate about the origin of mind-wandering (MW). Departing from current dominant views that implicate the executive functions system in MW, we here provide evidence for the alternative proposition that MW might be locally initiated due to an increase in sleep pressure in neural areas engaged during performance of a task.

Introduction

Mind-wandering (MW) is known to be pervasive (Killingsworth & Gilbert, 2010; Seli et al., 2018) and detrimental to behavior (e.g., Galera et al., 2012; Szpunar, Moulton, & Schacter, 2013). Influential accounts of MW share the idea that MW occurs due to modifications in the executive functions system. According to the *executive-resources* account, MW consumes executive resources drawing them away from the primary task (Smallwood & Schooler, 2006). In contrast, the *executive-failure* account states that MW is controlled by the executive system with the occurrence of MW linked to a failure of that system (McVay & Kane, 2010). At the junction of these proposals, the *executive-control* account suggests that MW indeed consumes executive resources, but that the negative behavioral consequences are related to executive control failures (Thomson et al., 2015).

Combining results from MW and sleep research, however, raises the interesting suggestion that MW could be related to local changes in primary task-related networks (Andrillon et al., 2019; Jubera-Garcia et al., 2021). Studies evidenced a positive relationship between the occurrence of MW and increasing sleep pressure (i.e., the biological, homeostatic drive for sleep; Carciofo et al., 2014; Poh et al., 2016). In these experiments, increased sleep pressure resulted from a trade-off between global states of wakefulness and sleep (i.e., participants extended wakefulness at the expense of sleep). Wakefulness and sleep, however, are not always discrete states, and can coexist simultaneously in different brain regions (D'Ambrosio et al., 2019; Siclari & Tononi, 2017). Furthermore, rodent data showed that local sleep during wakefulness is use-dependent; i.e., it can be triggered by overloading task-related neuronal circuits, and is associated with impairments in task performance (Vyazovskiy et al., 2011). Likewise, intracerebral recordings in sleep-deprived epileptic patients showed that instances of local sleep are directly related to commission errors in a psychomotor vigilance task (Nir et al., 2017). In healthy sleep-deprived participants, extensive use of task-related brain

areas resulted in locally increased sleep-like activity associated with decreased accuracy (Bernardi et al., 2015; Hung et al., 2013).

The findings that local sleep pressure is use-dependent and that MW frequency increases with sleep pressure raise the possibility that MW is related to use-dependent sleep pressure in task-related areas. Partially supporting this hypothesis is the finding that MW increases with time-on-task (Krimsky et al., 2017; Thomson et al., 2014). These results have been explained by the executive-control account assuming that executive control fades over time eventually leading to an increasing failure to allocate sufficient resources to the primary task (Thomson et al., 2015). We here posit the non-mutually exclusive hypothesis that changes in MW with time-on-task are not necessarily related to a decline of the executive system itself, but can also be due to a fading of the resources in the task-related areas because of a build-up of local sleep pressure (Andrillon et al., 2019; Jubera-Garcia et al., 2021).

In the present study, we investigated the hypothesis that MW is related to increased local sleep pressure in task-related brain regions using the texture discrimination task (TDT; Karni & Sagi, 1991). The TDT is a well-known visual discrimination learning task that comprises a central letter task (ensuring visual fixation) and a peripheral visual orientation task (see Figure 1 and the *Methods* for a detailed description), and that features interesting characteristics for the current purpose. First, visual discrimination learning, as measured by the orientation task, is restricted to the trained visual quadrant, suggesting that experience-dependent changes are taking place locally in the visual cortex (Deliens et al., 2014; Karni & Sagi, 1991). Second, performance in the orientation task deteriorates from one practice session to the other when sessions are spaced apart by a wake interval (Mednick et al., 2003), but can be restored after sleep (Deliens et al., 2014; Mednick et al., 2003). Third, this deterioration relates to decreased stimulus-driven activity in the projection areas of the trained visual quadrant in V1, and not to decreased attentional modulation (Mednick et al., 2009). Fourth,

shifting the target to an untrained visual quadrant (stimulating a different primary visual projection area) restores performance to baseline even in the absence of sleep, suggesting that performance deterioration is training condition-specific, and not merely a product of global fatigue. In sum, available evidence suggests that performance on the orientation task in the TDT deteriorates due to the build-up of sleep-pressure (because performance restores after sleep) and that this build-up is local (because performance restores when shifting the target to an untrained quadrant).

In the present experiment, participants performed four sessions of the TDT in one day. In the first three sessions, the same visual quadrant was trained. In the fourth session, the target's location shifted to a different quadrant. In line with previous work, we anticipated that performance on the orientation task of the TDT would deteriorate from the first to third session and recover on the fourth session. In each session, MW was recorded using both subjective (i.e., a probe-caught method) and objective measures (i.e., pupil's phasic response to the stimuli, e.g., Jubera-García et al., 2020; Unsworth & Robison, 2018). If MW is related to locally increased sleep pressure, both subjective and objective MW indicators should parallel the evolution of orientation performance across TDT sessions, with MW increasing over the first 3 sessions, and decreasing on the fourth session.

Experiment

Methods

Participants.

20 participants (M_{age} : 23.25 years, SD_{age} : 2.40; 16 females) with normal vision participated for money after signing informed consent. The Ethics Committee of the Université

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Libre de Bruxelles approved this study. Participants were asked to refrain from drinking alcohol and to sleep well on the previous day. In between sessions, sleeping and coffee were not allowed; light meals and quiet activities were suggested.

Stimuli and Material.

Testing was performed in a darkened room on a Mac OS X computer (version 10.7) and a Samsung SMB 1940 screen (60-Hz refresh rate, 1280 x 1024 resolution). The participants' head was positioned on a chin rest at 66 cm from the top of the screen. The screen thus covered a horizontal visual angle of 37° and a vertical visual angle of 30°. Pupil diameter and gaze position for the dominant eye were recorded at 500 Hz using an EyeLink 1000 system (SR Research, Ottawa, Canada) calibrated using a nine-point calibration setting prior to the experimental task. Stimulus presentation was programmed in Matlab (Mathworks, MA, USA) and Psychtoolbox (Pelli, 1997; Brainard, 1997). Stimuli were presented in white on a black background.

Design and Procedure.

TDT sessions. Four TDT sessions were administered on the same day at 10 AM, 12 PM, 2 PM and 4 PM. A single TDT session comprised 13 blocks of 50 trials each. A trial (Figure 1) started with the presentation of a fixation cross at the center of the screen until the participant pressed a key to initiate the trial. Next, a blank screen was displayed for 250 ms followed by the target display for 33 ms. The target display was composed of a background of 19×19 randomly jittered horizontal bars ($14^\circ \times 14^\circ$ visual angle in size) and the simultaneously displayed letter and orientation stimuli. The letter stimulus was a 'T' or 'L' letter, randomly rotated up to 360°

and displayed in the center of the target screen. The orientation stimulus was made of three diagonal bars, vertically or horizontally aligned and displayed in a specific visual quadrant at 4.2° eccentricity from the center of the screen (i.e., the position of the rotated letter). After the display of the target for 33 ms, a blank screen was presented for a variable duration (i.e., stimulus onset asynchrony; SOA) followed for 100 ms by a mask. The SOA progressively decreased from 460 to 60 ms across the 13 blocks of the session (i.e., 460, 360, 260, 240, 220, 200, 180, 160, 140, 120, 100, 80, and 60 ms). Participants were instructed to respond to the two targets in succession. They had first to decide if the centrally presented letter was a T or a L (referred to as the *letter task*), then to decide if the diagonal bars were vertically or horizontally aligned (referred to as the *orientation task*). Dedicated response keys for letter and orientation stimuli were labeled with stickers. In the TDT, perceptual discrimination training operates on the orientation stimuli presented in peripheral vision in the selected visual quadrant, whereas the simultaneous letter task ensures that participants always keep their gaze fixated on the center of the screen (as they have no sufficient time to initiate an ocular saccade before the presentation of the mask). In the first three sessions, orientation stimuli (i.e., the diagonal bars) were always presented in the same quadrant. In the fourth session, orientation stimuli were presented in the opposite quadrant (e.g., from the lower-left quadrant in the first three sessions to the upper-right quadrant in the fourth session). All possible pairs of visual quadrants were used, counterbalanced between participants. Participants were instructed to fixate the center of the screen during the entire session.

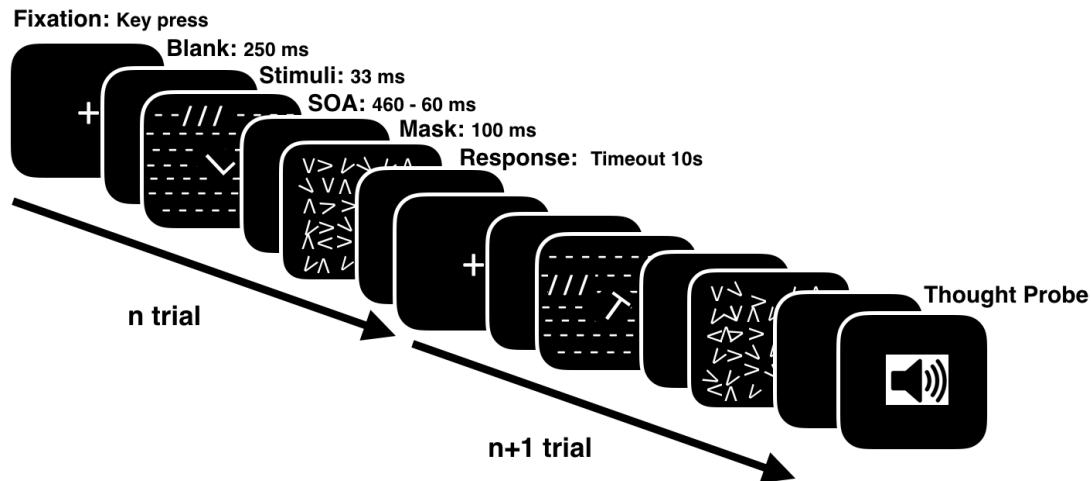


Figure 1. TDT trial timeline. In the TDT, participants must both identify the simultaneously presented stimulus in the center of the screen (either a rotated ‘L’ or ‘T’; the letter task) and stimulus presented in peripheral vision (i.e. vertical or horizontal disposition of three lines; the orientation task) in a specific visual quadrant (e.g. here, left superior), in this order. To assess MW, an auditory cue signaled a thought probe (4 per block, pseudorandomly interspersed with a minimum of six trials in between two thought probes).

Mind Wandering. To probe MW episodes during the TDT, four thought probes were introduced in each block (i.e., $13 \times 4 = 52$ thought probes per session) at pseudorandom points in time. The number of trials between thought probes was at least six. A thought probe was signaled by an auditory cue, prompting two questions that participants had to answer (Figure 1; Jubera-García et al., 2020). The first question concerned the content of their thoughts prior to the presentation of the thought probe: were their thoughts related or not to the content of the task (i.e., on- versus off-task thoughts)? The second question probed the intensity of the focus of their thoughts prior to the thought probe. Intensity ranged from 1 (low intensity) to 4 (high intensity). Participants provided their responses to the two questions by pressing dedicated responses keys covered with stickers stating “ON”–“OFF” (content) and numbered from 1 to 4 (intensity). We will use the terms content and intensity of thought throughout the article to identify these variables.

Fatigue, sleepiness and vigilance. We also controlled for the potential influence of global changes in sleepiness and fatigue on mind-wandering (e.g., Stawarczyk & D'Argembeau, 2016) using subjective Visual Analogue Scales (VAS), and monitored changes in vigilance using a psychomotor vigilance task (PVT; Basner & Dinges, 2011) at the beginning and at the end of every session. Before and after TDT administration, participants subjectively rated their degree of sleepiness and fatigue on VAS (VAS-sleepiness, Tanaka et al., 2014; VAS-fatigue, Lee et al., 1991), and performed on a 5-minute version of the PVT (Dinges & Powell, 1985) to estimate vigilance levels. In the PVT, participants must press the space bar as fast as possible at each occurrence of a number countdown on the screen. Stimuli are randomly presented at 3- to 15-seconds interval for 5 minutes.

One experimental session lasted about 55 to 70 minutes in total. At the beginning of the first session, participants were familiarized with the TDT by performing an easy version of the TDT (i.e., with an SOA of 600 ms) for 4 blocks of 16 trials each. During the first 4 trials of this familiarization, stimuli remained on the screen for five seconds to clearly show what the stimuli looked like.

Behavioral Data Analysis.

Analyses were conducted with Bayesian linear mixed-effect models (BLMMs) and uninformative priors in JASP (JASP Team, 2019). All data and analyses are available at <https://osf.io/2zjt3/>. Estimated contrast parameters with 95% highest posterior density interval (HPDI) that did not contain 0 are considered to support the presence of an effect because the probability that the parameters contribute to the statistical model is 95%. When comparing

models, stepwise model selection was based on the Watanabe Akaike Information Criteria (WAIC; Watanabe, 2013) which is particularly suitable for Bayesian settings. A smaller WAIC value implies that a model has a lower predictive error (i.e., has a better fit)..

Performance on the orientation task of the TDT was defined by the threshold (SOA) needed to achieve 80% accuracy (Karni & Sagi, 1991). This threshold was obtained by fitting the psychometric function of percentage correct for each SOA with a Weibull function¹ (Mednick et al., 2009) for all trials with a correct response to the letter task (e.g., Tamaki et al., 2020). The first two blocks (SOAs of 460 and 360 ms) were excluded because of highly erratic behavior (i.e., performance below the threshold of 80%).

Pupil Data Analysis.

Blinks were linearly interpolated (Kloosterman et al., 2015), and a low-pass, third-order Butterworth filter with a cutoff of 5 Hz was applied. Similar to the behavioral data, the first two TDT blocks were removed from the analyses. The stability of eye fixations was analyzed by median centering their location per participant before stimuli presentation (i.e., 250 ms). Trials on which participants were not fixating to the center (i.e., more than 2° away from the center) were removed from further analyses because this can distort a reliable measure of pupil size (Jubera-García et al., 2020; Kloosterman et al., 2015). This resulted in removing 11% of the trials. Inclusion of these trials, however, did not change the results. The first trial of each block was also removed from further analyses. Data were z-transformed and the phasic response was calculated as the difference between the mean baseline value of the pupil (i.e.,

¹ One session of one participant could not be fitted with this method due to complete separation of data (i.e., too little data points on the function's slope). This psychometric function was refitted using a Generalized Additive Model with Weibull distribution, which can handle cases of complete separation more easily (Knoblauch & Maloney, 2012)

250 ms of blank period prior to stimulus onset) and its highest deviation after stimulus onset (Gilzenrat et al., 2010). Phasic pupillary response per trial was used as the dependent variable in the BLMM.

Results

Task performance

To investigate if performance on the orientation task of the TDT would replicate earlier work, a BLMM containing a random intercept across participants and session (1 to 4) as a predictor (i.e. ordinal factor) was performed on the thresholds. Contrasts estimates showed that the threshold increased from session 1 to session 3, $\beta_{\text{Session3-Session1}} = 65.10$, $HPDI = [44.29, 85.27]$, and decreased again from session 3 to 4, $\beta_{\text{Session4-Session3}} = -40.21$, $HPDI = [-60.57, -19.00]$. Performance on the letter task was consistently high ($> 90\%$) and revealed a critically different pattern: only a slight decrease was observed from session 1 to 4, $\beta_{\text{Session4-Session1}} = -3.42$, $HPDI = [-5.08, -1.69]$, suggesting that the change in quadrant did not affect the participants' general motivation or ability to perform the task. The change in performance across sessions is presented in Figure 2A and Figure 2B for the orientation task and letter task, respectively.

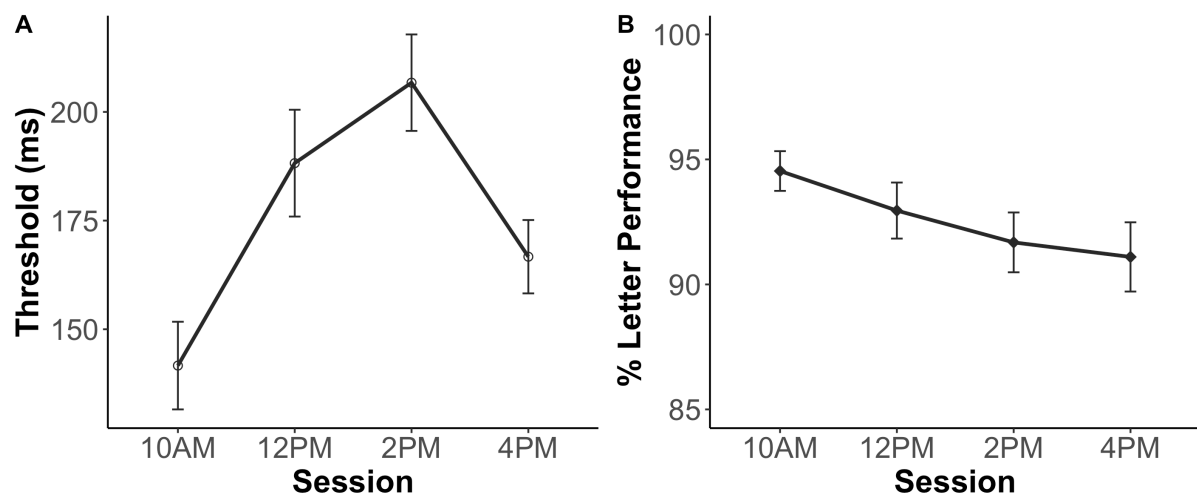


Figure 2. Performance in (A) the orientation task: An increase in the threshold (i.e., a decrease in performance) was observed from session 1 to 3 but was restored when the target was presented in a different visual quadrant in session 4. (B) the letter task: A continuous decrease in performance is observed from session 1 to session 4. Values represent the mean of raw data with error bars reflecting the standard error of the means.

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Subjective MW

To investigate if subjective MW followed the behavioral pattern across sessions, a Bayesian generalized LMM with a Poisson distribution containing a random intercept across participants, and Session (1 to 4), was fitted to the responses on the thought probes. Because prior work showed that behavioral performance was mostly related to probes at high intensity (i.e., high intensity On-task and high intensity Off-task; Jubera-Garcia et al., 2020), the model was fitted to the count of the high intensity On-task responses and to the high intensity Off-task responses. For the high intensity On-task responses (34.5%) there was a reliable effect for a decrease from session 1 to session 3, $\beta_{\text{Session3-Session1}} = -2.53$, $HPDI = [-4.22, -0.88]$, but no reliable increase from session 3 to session 4, $\beta_{\text{Session4-Session3}} = 0.29$, $HPDI = [-1.20, 1.98]$. For the high intensity Off-task responses (11.7%), no reliable effects were observed: $\beta_{\text{Session3-Session1}} = -0.00$, $HPDI = [-0.64, 0.60]$, and $\beta_{\text{Session4-Session3}} = -0.01$, $HPDI = [-0.59, 0.62]$. No effects were present for the same analysis on the low intensity probes. The counts of the responses for the different sessions are presented in Figure 3A.

Objective MW

A BLMM containing a random intercept across participants and Session as a predictor revealed a significant decrease of the phasic pupillary response from session 1 to 3, $\beta_{S3-S1} = -0.070$, $HPDI = [-0.091, -0.046]$. Critically, a significant increase was observed from session 3 to 4, $\beta_{S4-S3} = 0.026$, $HPDI = [0.003, 0.048]$ (Figure 3B).

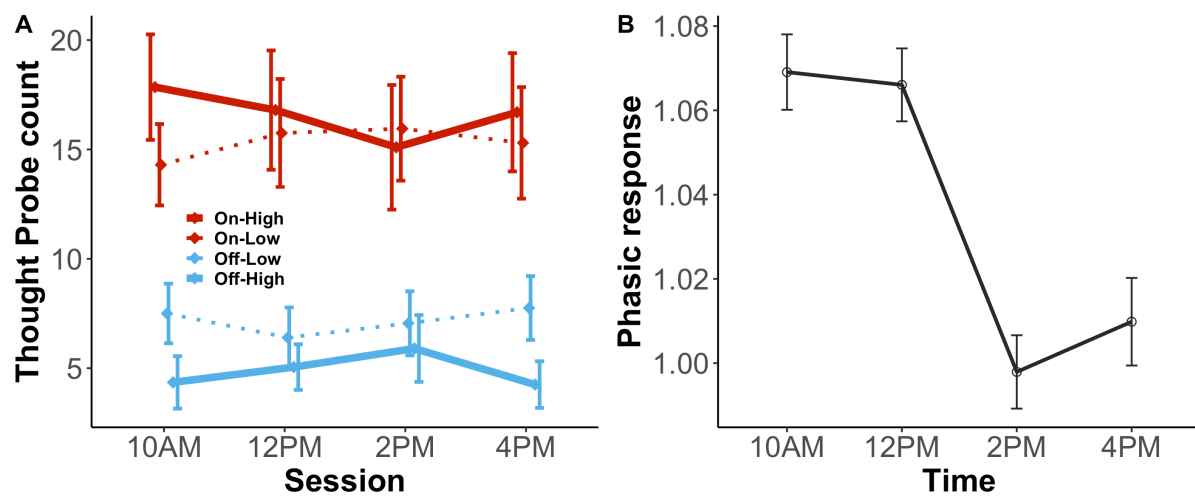


Figure 3. (A) Estimated number of responses to the thought probes reported per session and category. Solid lines show high intensity states, dotted lines show low intensity states. Blue: on-states; Red: off-states. (B) Mean phasic pupillary response with error bars reflecting the standard error of the means. Phasic pupillary response decreased from the first to the third session but increased again in the fourth session.

Because the results from the subjective and objective MW responses diverged and because the TDT is more demanding (both in terms of pace and difficulty) compared to other tasks typically used in MW research, it could be argued that the phasic pupillary response might not be a good proxy for MW in this study. Indeed, whereas the phasic pupillary response has been shown to be reliably related to subjective MW in other tasks (Jubera-García et al., 2020; Mittner et al., 2014; Smallwood et al., 2011; Unsworth & Robison, 2016), this relation might not be valid for

the TDT. A BLMM containing a random intercept across participants, and Content and Intensity as predictors, was therefore performed on the phasic pupillary response during a time window of five trials before a thought probe (because there were at least 6 trials in between thought probes). Only identical sessions were included in this analysis (i.e., the last session was excluded) to avoid a possible influence on the phasic pupillary response related to a visual change on the task. Results replicated previous research that have found a diminished phasic response preceding off-task (mean = 1.00, $SEM = 0.03$) compared to on-task reports (mean = 1.17, $SEM = 0.01$), $\beta_{OffTask-OnTask} = -0.052$, $HDPI = [-0.105, -0.003]$.

Performance as predictor of MW

To statistically assess whether MW was better predicted by performance on the orientation task compared to the letter task, an analysis that investigated the relation between the behavioral performance on these tasks and the phasic pupillary response was performed. Three models were therefore compared, containing a random intercept across participants, and performance on the orientation task and/or letter task as predictors, on the mean of the phasic pupillary response calculated per session. When comparing the full model (i.e., including performance on both tasks, $WAIC = 4.24$) to models with only one main effect (Performance Letter Task model, $WAIC = 3.83$; Performance Orientation task model, $WAIC = 2.28$), the best fitting model was the one including only performance on the orientation task as a main effect.

VAS Fatigue and Sleepiness

VAS-sleepiness and VAS-fatigue scores were separately analyzed with Session and Time (before vs. after the TDT) as fixed factors. This revealed a significant decrease in sleepiness scores from session 1 to 4 (mean $_{S1} = 0.70$, $SEM_{S1} = 0.04$; mean $_{S4} = 0.56$, $SEM_{S4} = 0.04$),

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$\beta_{sleepiness, S4-S1} = -0.14$, $HDPI = [-0.22, -0.05]$, and similarly in fatigue scores from session 1 to 4 (mean $S1 = 0.70$, $SEM_{S1} = 0.03$; mean $S4 = 0.54$, $SEM_{S4} = 0.04$), $\beta_{fatigue, S4-S1} = -0.15$, $HDPI = [-0.22, -0.09]$.

The effect of Time was also significant for both the sleepiness and fatigue scores: sleepiness was higher after (mean = 0.77, $SEM = 0.02$) than before (mean = 0.50, $SEM = 0.03$) the sessions, $\beta_{sleepiness, after-before} = 0.27$, $HDPI = [0.21, 0.32]$, and fatigue was also scored higher after (mean = 0.71, $SEM = 0.02$) than before (mean = 0.56, $SEM = 0.03$) the sessions, $\beta_{fatigue, after-before} = 0.15$, $HDPI = [0.10, 0.20]$.

PVT

An analysis on the reciprocal transform (1/RT; Basner et al., 2011) with Session as the only predictor revealed no significant effect, $\beta_{4-1} = -0.03$, $HPDI = [-0.11, 0.05]$. Descriptive statistics show that the reciprocal transform remains very similar between sessions: mean $Session1 = 3.41$, $SEM = 0.08$; mean $Session2 = 3.41$, $SEM = 0.08$; mean $Session3 = 3.38$, $SEM = 0.07$; mean $Session4 = 3.38$, $SEM = 0.08$.

Discussion

Our results showed the typical pattern of behavioral results observed across different sessions in the TDT: The threshold for the orientation task increased (i.e., performance worsened) from session 1 to session 3, but decreased (i.e., better performance) from session 3 to session 4 when the target changed quadrants. This pattern of results was mirrored in the objective measure for MW (i.e., the phasic pupillary response), but not in the subjective measure. Importantly, the phasic pupillary response related reliably to the content of the participants' thoughts, supporting our hypothesis that MW might be locally initiated due to an increase in sleep

pressure in neural areas engaged during task performance. Furthermore, model comparison analysis confirmed the qualitative observation that the pattern of results found for the pupil response is specifically related to performance on the orientation task and hence, to the local depletion of resources.

The unexpected discordance between subjective and objective markers of MW could be explained by the small number of MW reports in our study. Only 25% of the MW reports were off-task responses (compared to 30-65% in other studies; Forster & Lavie, 2009; Seli et al., 2013; Smilek et al., 2010). This relative small number might be related to the high complexity of the TDT, and the task demands could have biased the participants' responses (Weinstein, 2018). Previous work demonstrated that subjective reports of MW can be manipulated without changing the incidence of objective MW (Seli et al., 2013).

It could be argued that participant's motivation can explain our results: The small change in the task would have caused a renewed interest in the task. However, this renewed interest was not visible for performance on the central letter task of the TDT nor in the results from the PVT. There were no signs of overall changes in fatigue, sleepiness or motivation. Although we cannot exclude a renewed motivation for the orientation task when the target changes quadrants, a previous work showed that this is likely not the case. Ofen, Moran and Sagi (2007) looked at the performance deterioration in the orientation task of the TDT within a single session. In one of their experiments, irrelevant targets were presented in the opposing quadrants throughout the experiment (i.e., together with oriented lines in a specific quadrant to which participants had to respond, the opposite quadrant also contained oriented lines that the participant should ignore). Interestingly, when the relevant oriented lines changed quadrants (i.e., the previous irrelevant lines in the opposite quadrant now became the relevant targets) behavioral performance did not recover. This strongly suggests that behavioral performance on the orientation task is related to low-level neuronal processes in the cortical receptive fields. If

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a change of quadrants would increase the participants' motivation, performance should have increased again.

The current results therefore may challenge theories that put the executive system as the driving force behind MW. Because the task requirements remained stable across all TDT sessions, it is unclear why changes in the executive system would take place according to the pattern of results observed here. The *executive-resources* account states that MW occurs because the executive system draws resources away from the primary task. Our results rather suggest that MW occurs because resources get drained from the primary task. It is not the executive system that decides that less resources should go the primary task, but that the resources get depleted by performing the task and that this causes MW (either mediated by the executive system or not remains to be investigated). The *executive-failure* account posits that MW occurs because of a failure of the executive system. Our results suggest that it is rather a failure of the task-related areas (here, the receptive field in the visual cortex). Finally, the *executive-control* account articulates explicitly that the decrease in task-related processing over time occurs because of a reduction in executive control causing an insufficient allocation of resources to the primary task. Our result, however, suggest that it is not executive control that fades over time, but rather the information being processed in the task-related areas. In sum, our results go beyond the classical accounts of MW by suggesting that it is not a change in the executive system (be it a change in the resource allocation, a failure or fading over time) that drives the attentional shift, but that it is instead a depletion of resources, or a decreased functioning over time of the task-related areas. Still, these accounts are not mutually exclusive.

Notwithstanding, we argue that the increase in MW with time-on-task is due to changes in the task-specific 'system'. We propose that these changes reflect a depletion of task-related resources linked to an increase in local sleep pressure, and that this causes the mind to turn to task-unrelated thoughts (i.e., its default state; McVay & Kane, 2010; Thomson et al., 2015).

This entails that task-related brain areas would become less responsive over time (as observed in the primary visual cortex for the TDT; Mednick et al., 2009), and that this might trigger a shift to the default mode network known to be involved in MW (e.g., Christoff et al., 2009).

Our proposal fits with recent work showing that the frequency of MW increases more at high cognitive load compared to a low load task with time-on-task (Krimsky et al., 2017). According to our local depletion account, the high load task depletes local resources more quickly and would therefore cause a sharper increase in the likelihood that participants will MW. Similarly, the increase in MW after sleep deprivation was only observed in a task with high load (Poh et al., 2016). Also here, the overall local sleep pressure accumulated with the stronger build-up of task-specific sleep pressure in the high load task could have caused the increase in MW.

To conclude, this study does not suggest that the executive system has no role in MW, but that some instances of MW could be caused by a depletion of local, task-related resources, making it a natural, biological consequence of neural activity.

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