LETTER

REPLY TO CSIFCSÁK AND MITTNER:
Fitting data to neural models of mind-wandering

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We recently provided evidence for a nonunitary account of default mode network (DMN) function, because DMN activity was associated with greater mind-wandering (MW) on the one hand, but with behavioral stability on the other (1). Csifcsák and Mittner (2) suggest that their nonunitary model of MW could explain these results. The model predicts distinct neural correlates for attentional states characterized as "off-focus" (a subconscious, exploratory state) versus "active MW" (a focus on an internal train of thought) (3). They offer thought-provoking consequences for interpreting activity that we reported in the frontoparietal network (FPN; no relationship with MW) and medial temporal lobe (MTL) subsystem of the DMN (no relationship with behavioral stability).

According to their model, the high cognitive demand of the task in our study resulted in more off-focus than active MW states. Both states are predicted to have higher behavioral variability (differing in degree) but are expected to dissociate based on the specific DMN subsystems engaged (3). Consistent with the model, we found that MW was associated with greater behavioral variability at both intra- and interindividual levels (1). However, we believe that these relationships can at least partly be attributed to active MW. Beyond the self-reports during task performance, which required awareness that MW had occurred, postexperiment qualitative interviews revealed that participants consciously engaged in off-task trains of thought about the past and future. We acknowledge the possibility of prevalent off-focus states, but our measures did not allow us to capture such subconscious phenomena.

Even if active MW states were more prevalent than off-focus, we would still not be entirely surprised that a relationship between MW and FPN activation was absent. In previous studies involving both the low-demand task of avoiding structured thinking (4) and the potentially high "cognitive demand" of experimental pain (5), self-reported (conscious) MW has been associated with DMN but not FPN activation. It is possible that FPN activity reflects "cognitive control" aspects of MW, as often assumed in the field, but more studies are needed to provide clear evidence.

Regarding the lack of correlation between behavioral stability and MTL subsystem activity, there was a trend in the same direction as in the other DMN subsystems. Compared with those other subsystems, the MTL subsystem contains regions with poorer fMRI signal to noise (6). It is possible that technical limitations masked an effect that was congruent with the effect of other DMN regions. Thus, it remains unclear whether off-focus states could explain our MTL subsystem results.

Taken together, we remain open to the model-based interpretations of Csifcsák and Mittner, but we underscore that alternative explanations are possible. Importantly, a model that inherently yokes MW states with behavioral variability cannot account for our key result: Each factor independently predicted DMN activity. Formal neural models of MW, such as the one proposed by Mittner et al. (3), remain rare in the field but are vital to advancement. The value will be fully realized if such models are continuously updated to account for emerging findings that may be either supportive or contradictory.

1 Kucyi A, Esterman M, Riley CS, Valera EM (2016) Spontaneous default network activity reflects behavioral variability independent of mind-wandering. *Proc Natl Acad Sci USA* 113:13899–13904.

2 Csifcsák G, Mittner M (2017) Linking brain networks and behavioral variability to different types of mind-wandering. *Proc Natl Acad Sci USA* 114:E6031–E6032.

3 Mittner M, Hawkins GE, Boekel W, Forstmann BU (2016) A neural model of mind wandering. *Trends Cogn Sci* 20:570–578.

4 Vanhaudenhuyse A, et al. (2011) Two distinct neuronal networks mediate the awareness of environment and of self. *J Cogn Neurosci* 23:570–578.

5 Kucyi A, Salomons TV, Davis KD (2013) Mind wandering away from pain dynamically engages antinociceptive and default mode brain networks. *Proc Natl Acad Sci USA* 110:18692–18697.

6 Schacter DL, Wagner AD (1999) Medial temporal lobe activations in fMRI and PET studies of episodic encoding and retrieval. *Hippocampus* 9:7–24.

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