Supplemental Material:

"Increasing Mind Wandering With Accelerated Intermittent Theta Burst Stimulation Over the Left Dorsolateral Prefrontal Cortex"

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Supplemental Methods

Participants

Participants were asked their age and gender, as well as whether they had any musical experience (yes or no), and if they did, the number of years they had been playing which instrument. Furthermore, they rated their experience with meditation practice from (1) no experience, (2) some experience, (3) moderate experience or (4) much experience. Finally, participants were asked whether they had any prior transcranial magnetic stimulation (TMS) experiences (yes or no), and if yes, how many times they had received TMS.

Only one participant reported a single experience with TMS. In total, 24 participants reported to have musical experience ranging from a couple of months to 17 years (M = 3.7, SD = 5.04). Half of our participants reported to have "some experience" with meditation (24), while only 2 reported to have "moderate experience" with meditation and the rest had no experience with meditation.

Inclusion criteria

Participants could not have metal implant, or electronic devices in the body, needed good or corrected vision and fluent speakers of English or Norwegian. In addition, participants had to fulfil a session-specific inclusion criteria before starting. Participants had to be (1) well rested, (2) not be too hungry, (3) not affected by any psychotropic drugs (aside from nicotine and caffeine), (4) not wear too much makeup, (5) not affected by medicine that affects the central nervous system and (6) no earrings, piercings, or jewellery. Furthermore, participants were asked “On a scale of 1-10 how tired are you?” answered on a scale from 1

(extremely tired) to 10 (fully rested). Then participants were asked “Do you expect that brain stimulation will influence your performance on the task?”, answered were discrete: (1) “No, I have no expectations”, (2) Yes, it’s going to improve my performance”, (3) “Yes, it’s going to reduce my performance”, (4) “Yes, but don’t know to what extent”, (5) “I don’t know”.

Thought Probes

Two additional thought probes were used in our study. The second question related to mind blanking (MB; Ward & Wegner, 2013), where participants were asked whether the content of the MW episode was reportable: “To the degree to which you were not focusing on the task, were you thinking about nothing or were you thinking about something?”, answered on a Likert scale from 1 (clearly nothing) to 4 (clearly something). The final, third probe asked about the participants' intention to stay on-task or to mind wander (Seli et al., 2015, 2016): “Were you deliberate about where you focused your attention (either on-task or elsewhere) or did it happen spontaneously?”, answered on a Likert scale from 1 (clearly spontaneous) to 4 (clearly deliberate).

Simulation of the NIBS Protocol

We used SimNIBS version 3.2.3 (Saturnino et al., 2019) to model the electric field elicited by the TMS protocol in the brain. We used the Magstim 70mm figure 8 coil which is similar to our MAG and More Double coil PMD70-pCool coil which was not supported directly. Simulation parameters were identical to our stimulation protocol, i.e., MNI coordinates x = -44.23, y = 29.48, z = 21.62 and the coil was positioned at a 45° angle in posterior-lateral orientation relative to the midline. The coil-head distance was set to 4 mm. For illustration of the target area in Figure 2 in the main text, we used the Schaefer et al. (2018) atlas with the 17 network parcellation and 400 parcels to outline the dorsolateral prefrontal cortex (DLPFC, green, Figure 2b main text). The parcels used to define the left

DLPFC in this figure were "ContA PFClv_1" (index 128), "ContA PFClv_2" (129) and "ContA PFCl_2 (131)".

Blinding Procedure

While participants were engaging in the baseline round of the FT-RSGT, one of the researchers left the room while the other researcher started the blinding procedure. The researcher responsible for blinding opened the envelope corresponding to the participants' code, which contained the predetermined stimulation condition created by a researcher that was not taking part in data-collection (MM). Because we only had access to a single coil reference for the Localite TMS navigator, we had to reuse the one we had. Therefore, to ensure proper blinding, the coil reference was always removed regardless of stimulation condition. The coil was then either swapped (i.e., sham condition) or not, and the coil reference was placed on the correct (real/sham) coil. Unfortunately, the sham and active coil had several distinguishing features (small markings due to the production of the coils) that could theoretically enable the researchers, who were intimately familiar with the coils, to distinguish them. Thus, we covered the coil with a fabric tube (a neck gaiter – one end at the handle of the coil and the end at the coil reference). The blinding researcher would recalibrate the coil reference in the software before covering the coil. Furthermore, the end of the coil cables also had distinguishing marks, and we covered that part with another fabric tube (a cut sock). The other coil was placed in a box for the remainder of the experiment. Thereafter, the blinding researcher left the room and did not further participate in experimentation with that participant. Lastly, after the session with a participant was concluded, the blinding researcher would undo the blinding and set the lab back up as it was when the experiment started.

Procedure

During hotspot hunting, at the predetermined coordinates (x = -40, y = -20, z = 52), we moved around within a radius of 2 cm to find the best location (hotspot). The coil was held at

a 45° angle in posterior-lateral orientation relative to the midline. The maximum stimulator output (MSO) was first set to 35 % and was increased by steps of 5-10 % if no motor evoked potentials (MEPs) reached 50 μV (plus noise). The area that yielded the most consistent MEP, defined as a peak in the EMG above 50 μV in the time-window 20-40 ms post-pulse was chosen as the motor hotspot. Thereafter, we reduced the MSO to 35 % and increased it with steps of 5 % until we reached 5 out of 10 MEPs. Then we reduced the MSO with steps of 1 % until we did not reach 5 out of 10 MEPs and used that value plus 1 as that participant's RMT (Rossini et al., 2015).

For the experimental task, participants were moved to a different compartment and seated in front of a computer screen (HP EliteDisplay E241i). They were seated approximately 70 cm from the screen, with the fixation cross taking up 0.9 degree of visual angle. Two speakers were seated right next to the monitor with a peak volume of 70dB (measured right in front of where participants were sitting).

Post-Experiment Questions

After the experiment, participants were asked: “Did you use any special strategy to create random sequences?”, answered freely while the experimenter took notes. Next, they were asked “Do you have any remarks about the task itself?”, “When you reported not being focused on the task (off-task), what were you thinking of?” and “Do you have any other comments?” all of which were asked verbally, and the answers recorded by the experimenter. Then participants had to guess what stimulation condition they thought they received, answered either as “real stimulation” or “fake stimulation”. They were then asked to rate how confident they were regarding their answer to the question about stimulation received, answered on a 7-point Likert scale from 1 (not confident) to 7 (very confident). In the participants’ second session, an additional question was asked: “Would you change your belief about which stimulation you first received, knowing what you know now?”, answered

as “yes”, “not sure” or “no”. They were asked, “How distracted were you by wearing the subject tracker on the head while doing the task?”, answered on a 7-point Likert scale from 1 (not distracted at all) to 7 (very distracted). Furthermore, they were asked to “Please consider how motivated you were to produce random sequences when the experiment started”, answered on a 7-point Likert scale from 1 (not very motivated) to 7 (very motivated). They were then asked, “When you answered a question about how focused you were on the task at hand, how sure were you of your answer?”, answered on a 7-point Likert scale from 1 (not at all) to 7 (extremely).

The researchers also answered a blinding questionnaire: “Which stimulation do you think the participant received today?”, answered as either real or sham stimulation. Then they rated “How confident are you in your answer to the question above?”, on a Likert scale ranging from 1 (Not confident; 4, moderately confident) and 7 (Very confident).

Supplemental Results

Table S1

Blinding Guesses for Participants and Researchers

True state	Participant guess			Researcher guess		
Session 1	False	True	Total	False	True	Total
False	7	13	20	9	11	20
True	9	11	20	8	12	20
Total	16	24	40	17	23	40
Session 2						
False	7	13	20	12	8	20
True	8	12	20	8	12	20
Total	15	25	40	20	20	40

Note. Both Fisher exact and Chi-squared p’s > .343.

Even when considering the participants' ability to "change their belief" about which stimulation they received after the second session, they still did not reach a level significantly above chance ($X^2(1, N = 20) = 2.53$, $p = .111$; Fisher Exact $p = .111$).

Side Effects of the Stimulation

Generally, side effects following the TMS were low. The most reported side effect was sleepiness (Sham: $M = 1.88$, $SD = 0.85$; Real: $M = 2$, $SD = 0.88$) and trouble concentrating (Sham: $M = 1.68$, $SD = 0.80$; Real: $M = 2$, $SD = 0.88$). Participants did not, however, believe that these side effects were related to the TMS (Sleepiness: Sham: $M = 1.9$, $SD = 1.08$; Real: $M = 1.82$, $SD = 0.90$; Trouble concentrating: Sham: $M = 1.82$, $SD = 1.03$; Real: $M = 1.98$, $SD = 1.19$). Reports of scalp pain were low, but higher ($M_{diff} = -0.15$) for real stimulation ($M = 1.35$, $SD = 0.62$) than sham stimulation ($M = 1.20$, $SD = 0.46$). Similarly, the relation of scalp pain to the TMS was low, but higher ($M_{diff} = -0.3$) for real stimulation ($M = 1.65$, $SD = 1.27$) than for sham stimulation ($M = 1.35$, $SD = 0.86$). Despite these differences, we did not find them to be significantly different for either symptoms or relation to TMS between real and sham stimulation. Only the side effect of trouble concentrating reached significance ($t(39) = -2.48$, $p = .017$; see Table S1 and Figure S1 for an overview).

Table S2

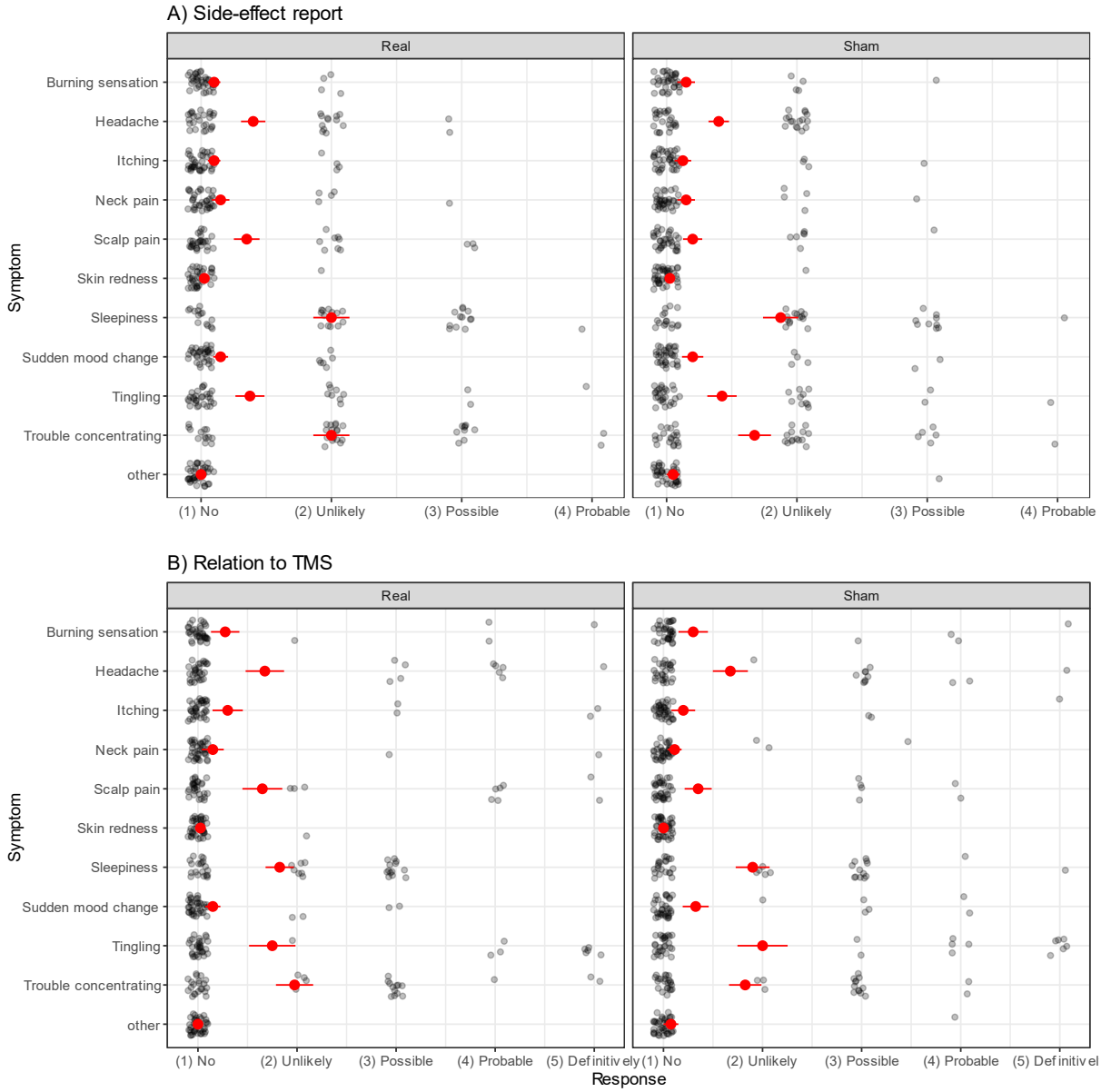
Side Effects of the Transcranial Magnetic Stimulation (TMS)

	Symptom report					Relation to TMS				
	Sham		Real			Sham		Real		
Symptom	*M*	*SD*	*M*	*SD*	M_{diff}	*M*	*SD*	*M*	*SD*	M_{diff}
Burning sensation	1.15	0.43	1.10	0.30	0.05	1.30	0.94	1.27	0.91	0.03
Headache	1.40	0.50	1.40	0.59	0.00	1.68	1.12	1.68	1.23	0.00
Itching	1.12	0.40	1.10	0.30	0.02	1.20	0.76	1.30	0.97	-0.10
Neck pain	1.15	0.43	1.15	0.43	0.00	1.11	0.45	1.15	0.70	-0.04
Scalp pain	1.20	0.46	1.35	0.62	-0.15	1.35	0.86	1.65	1.27	-0.30
Skin redness	1.02	0.16	1.02	0.16	0.00	1.00	0.00	1.02	0.16	-0.02
Sleepiness	1.88	0.85	2.00	0.88	-0.12	1.90	1.08	1.82	0.90	0.07
Sudden mood change	1.20	0.52	1.15	0.36	0.05	1.32	0.83	1.15	0.48	0.18
Tingling	1.42	0.71	1.38	0.70	0.05	2.00	1.60	1.75	1.48	0.25
Trouble concentrating	1.68	0.80	2.00	0.88	-0.32	1.82	1.03	1.98	1.19	-0.15
other	1.05	0.32	1.00	0.00	0.05	1.07	0.47	1.00	0.00	0.07

Note. Symptom reports are reported using four categories: (1) absent, (2) mild, (3) moderate, and (4) severe. The relation of the symptom to the TMS are answered using 5 categories: (1) no, (2) unlikely, (3) possible, (4) probable, and (5) definitively. $M_{diff.}$ = difference in mean between real and sham condition.

Figure S1

Participants' Reported Side-Effect and Relation to Transcranial Magnetic Stimulation (TMS)



Analysis of Content and Focus of MW

For the second (mind blanking, MB) and third (spontaneous mind wandering, SMW) thought probe, we used two separate ordered-probit model. For the MB and SMW probes, we only used responses preceded by a MW report.

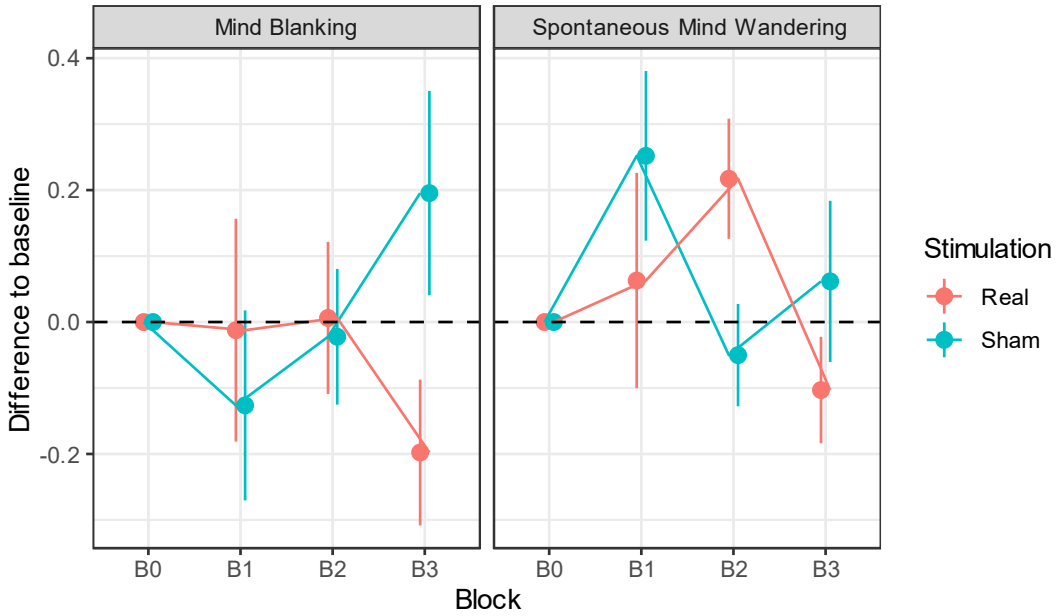
For MB, there was very strong evidence that MB increased within each block, $b = 0.08, [0.02,0.15], p^{+} = 0.99, \mathrm{ER}^{+} = 129.43$. However, between blocks, there was evidence for a reduction in MB responses to the first block (B0 to B1: $b = -0.10, [-0.36,0.18], p^{-} =$

$0.77, \mathrm{ER}^- = 3.36$), which was moderate for the second block (B0 to B2: $b = -0.18, [-0.46, 0.07], p^- = 0.91, \mathrm{ER}^- = 9.58$), but anecdotal for the last block (B0 to B3: $b = -0.06, [-0.36, 0.20], p^- = 0.66, \mathrm{ER}^- = 1.98$). For the real stimulation, there was anecdotal evidence for a decrease in MB response after the first stimulation ($b = -0.06, [-0.44, 0.30], p^- = 0.63, \mathrm{ER}^- = 1.69$), anecdotal evidence for an increase after the second stimulation ($b = 0.05, [-0.33, 0.42], p^+ = 0.60, \mathrm{ER}^+ = 1.51$), and moderate evidence for a decrease in MB responses after the third stimulation ($b = -0.31, [-0.69, 0.08], p^- = 0.94, \mathrm{ER}^- = 16.54$).

Regarding spontaneous MW (SMW), there was only anecdotal evidence for an increase in SMW within the blocks, $b = 0.02, [-0.04, 0.09], p^+ = 0.77, \mathrm{ER}^+ = 3.27$. There was moderate evidence that SMW increased from the baseline to B1 ($b = 0.19, [-0.08, 0.46], p^+ = 0.91, \mathrm{ER}^+ = 10.26$) and B2 ($b = 0.21, [-0.07, 0.47], p^+ = 0.93, \mathrm{ER}^+ = 14.08$), while there was very strong evidence that SMW increased to the third block ($b = 0.28, [-0.00, 0.56], p^+ = 0.97, \mathrm{ER}^+ = 33.48$). As for the real stimulation over blocks compared to baseline, SMW indicated anecdotal evidence for a decrease in the first block (stimulation × B1: $b = -0.17, [-0.57, 0.19], p^- = 0.81, \mathrm{ER}^- = 4.40$), and anecdotal evidence for an increase in the second block (stimulation × B2: $b = 0.13, [-0.28, 0.48], p^+ = 0.75, \mathrm{ER}^+ = 2.96$), and moderate evidence for a decrease to the third block (stimulation × B3 $b = -0.21, [-0.60, 0.18], p^- = 0.85, \mathrm{ER}^- = 5.57$).

Figure S2

Mind Blanking and Spontaneous Mind Wandering Reports Split by Stimulation



Note. Figure by Aasen, S. R., 2024; available at https://doi.org/10.6084/m9.figshare.25472137.v1 under the CC-BY 4.0 license.

Table S3

Bayesian Regression Models for Mind Wandering (MW), Mind blanking (MB) and Spontaneous MW

	MW			MB			Spontaneous MW		
	b	HDI	p^d	b	HDI	p^d	b	HDI	p^d
Coefficients[1]									
Threshold1	-0.44*	[-0.61, -0.27]	1.00	-0.52*	[-0.77, -0.28]	1.00	-1.77*	[-2.02, -1.53]	1.00
Threshold2	0.66*	[0.49, 0.83]	1.00	0.54*	[0.30, 0.78]	1.00	-0.91*	[-1.14, -0.68]	1.00
Threshold3	1.64*	[1.47, 1.82]	1.00	1.21*	[0.95, 1.45]	1.00	0.29*	[0.07, 0.52]	0.98
Trial	0.20*	[0.17, 0.24]	1.00	0.08*	[0.03, 0.14]	0.99	0.02	[-0.03, 0.08]	0.77
Stimulation (B0)	0.05	[-0.07, 0.18]	0.76	0.01	[-0.23, 0.24]	0.53	-0.03	[-0.26, 0.21]	0.59
B1	0.02	[-0.10, 0.14]	0.61	-0.10	[-0.33, 0.13]	0.77	0.19	[-0.04, 0.42]	0.91
B2	0.12	[-0.00, 0.24]	0.95	-0.18	[-0.41, 0.04]	0.91	0.21	[-0.02, 0.43]	0.93
B3	0.03	[-0.09, 0.15]	0.67	-0.06	[-0.29, 0.17]	0.66	0.28*	[0.03, 0.51]	0.97
B1 x stimulation	0.14	[-0.04, 0.31]	0.90	-0.06	[-0.38, 0.26]	0.63	-0.17	[-0.50, 0.15]	0.81
B2 x stimulation	0.21*	[0.03, 0.38]	0.97	0.05	[-0.26, 0.36]	0.60	0.13	[-0.20, 0.44]	0.75
B3 x stimulation	0.16	[-0.01, 0.33]	0.93	-0.31	[-0.63, 0.01]	0.94	-0.21	[-0.53, 0.12]	0.85
Model fit									
Sigma (subjects)	0.59	[0.48, 0.72]	1.00	0.63	[0.50, 0.79]	1.00	0.53	[0.40, 0.67]	1.00
R2	0.23	[0.21, 0.25]		0.23	[0.20, 0.27]		0.15	[0.11, 0.19]	
LOOIC	8255.12	(SE=65.57)		2693.64	(SE=41.24)		2446.40	(SE=47.30)	

[1]*: $p^d > 0.95$

Table S4

Bayesian Regression Models for Behavioural Variability (BV) and Approximate Entropy (AE)

	BV			AE		
	b	HDI	p^d	b	HDI	p^d
Coefficients[1]						
Intercept	-0.05	[-0.22, 0.11]	0.70	0.09	[-0.09, 0.27]	0.80
Trial	0.11*	[0.09, 0.13]	1.00	0.01	[-0.01, 0.03]	0.79
Stimulation (B0)	0.12*	[0.03, 0.22]	0.99	-0.01	[-0.11, 0.08]	0.61
B1	-0.00	[-0.09, 0.09]	0.52	-0.14*	[-0.24, -0.05]	0.99
B2	0.11*	[0.02, 0.20]	0.97	-0.17*	[-0.26, -0.07]	1.00
B3	-0.04	[-0.13, 0.05]	0.77	-0.15*	[-0.24, -0.06]	1.00
B1 x stimulation	-0.00	[-0.13, 0.12]	0.53	0.11	[-0.02, 0.25]	0.92
B2 x stimulation	-0.15*	[-0.28, -0.02]	0.98	0.05	[-0.08, 0.18]	0.75
B3 x stimulation	-0.09	[-0.21, 0.04]	0.87	0.03	[-0.10, 0.16]	0.67
SD (subjects)	0.59*	[0.49, 0.72]	1.00	0.60*	[0.49, 0.72]	1.00
Model fit						
SD	0.82	[0.80, 0.83]	1.00	0.82	[0.80, 0.84]	1.00
R^2	0.33	[0.31, 0.35]		0.33	[0.31, 0.35]	
LOOIC	8625.12	(SE=121.99)		8638.10	(SE=169.15)	

[1]*: $p^d > 0.95$

References

Rossini, P. M., Burke, D., Chen, R., Cohen, L. G., Daskalakis, Z., Di Iorio, R., Di Lazzaro, V., Ferreri, F., Fitzgerald, P. B., George, M. S., Hallett, M., Lefaucheur, J. P., Langguth, B., Matsumoto, H., Miniussi, C., Nitsche, M. A., Pascual-Leone, A., Paulus, W., Rossi, S., … Ziemann, U. (2015). Non-invasive electrical and magnetic stimulation of the brain, spinal cord, roots and peripheral nerves: Basic principles and procedures for routine clinical and research application. An updated report from an I.F.C.N. Committee. *Clinical Neurophysiology*, *126*(6), Article 6. https://doi.org/10.1016/j.clinph.2015.02.001

Saturnino, G. B., Puonti, O., Nielsen, J. D., Antonenko, D., Madsen, K. H., & Thielscher, A. (2019). SimNIBS 2.1: A Comprehensive Pipeline for Individualized Electric Field Modelling for Transcranial Brain Stimulation. In S. Makarov, M. Horner, & G. Noetscher (Eds.), *Brain and Human Body Modeling: Computational Human Modeling at EMBC 2018* (pp. 3–25). Springer International Publishing. https://doi.org/10.1007/978-3-030-21293-3_1

Schaefer, A., Kong, R., Gordon, E. M., Laumann, T. O., Zuo, X.-N., Holmes, A. J., Eickhoff, S. B., & Yeo, B. T. T. (2018). Local-Global Parcellation of the Human Cerebral Cortex from Intrinsic Functional Connectivity MRI. *Cerebral Cortex (New York, NY)*, *28*(9), 3095–3114. https://doi.org/10.1093/cercor/bhx179

Seli, P., Carriere, J. S. A., & Smilek, D. (2015). Not all mind wandering is created equal: Dissociating deliberate from spontaneous mind wandering. *Psychological Research*, *79*(5), Article 5. https://doi.org/10.1007/s00426-014-0617-x

Seli, P., Risko, E. F., Smilek, D., & Schacter, D. L. (2016). Mind-Wandering With and Without Intention. *Trends in Cognitive Sciences*, *20*(8), 605–617. https://doi.org/10.1016/j.tics.2016.05.010

Ward, A. F., & Wegner, D. M. (2013). Mind-blanking: When the mind goes away. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00650