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Chronotype and Time of Day Effects in Oddball Task Performance: Behavioural and Cerebral Correlates

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ABSTRACT

Circadian rhythms and inter-individual differences in sleep–wake preferences, or chronotypes, influence cognitive performance. The synchrony effect—the alignment of time of day with chronotype—modulates attention, memory, and executive control. This study examined behavioural and neural correlates of synchrony effects during an auditory oddball task performed in morning (1.5 h after wake-up) and evening (10.5 h after wake-up) sessions by extreme morning-type ($n = 16$) and evening-type ($n = 15$) young (age range: 22–32 y.o.) individuals. Behaviourally, no main, nor interaction effects of chronotype or time of day were observed for overall reaction time metrics (all $p > 0.05$). However, overall reaction times during the task were longer in the final third of the task in the evening compared to the morning session for morning but not evening types ($p < 0.05$). Functional magnetic resonance imaging (fMRI) revealed neural correlates underlying the synchrony effect: the inferior frontal cortex (IFC) showed higher task-related activation at optimal times (morning for morning types, evening for evening types, $p_{corr} < 0.05$), putatively reflecting enhanced top-down control. Conversely, a medial orbitofrontal region (mOFC), part of the default mode network, was more active at non-optimal times ($p_{corr} < 0.05$), consistent with reduced task engagement and internally directed processes. These findings suggest that synchrony effects interact with time-on-task-dependent effects with implications for sustained attention in real-world settings.

1 | Introduction

Human cognition is embedded within a biological temporal framework. Circadian rhythms, orchestrated by the suprachiasmatic nucleus, regulate fluctuations in alertness, vigilance, and executive functioning across the 24-h cycle (Cajochen and Schmidt 2025; Schmidt et al. 2007). Importantly, individuals differ in their preferred timing of wakefulness and sleep, commonly referred to as chronotype (Roenneberg and Merrow 2007). Morning types generally perform optimally in the earlier hours of the day, whereas evening types reach their peak later in the day (May et al. 2023). The interaction between time of day and chronotype gives rise to the synchrony effect: cognitive performance is enhanced at times of day aligned with one's chronotype preference and diminished at misaligned times (May 1999). Synchrony effects have been observed across diverse cognitive domains, including working memory (e.g., Hasher et al. 2005), executive control (e.g., Schmidt, Peigneux, Cajochen, and Collette 2012), and decision-making (e.g., Yoon et al. 2000). Yet, their impact on simple attentional paradigms such as the oddball task remains less explored.

At the cerebral level, it was observed that during a sustained attention task, activity of subcortical arousal centres differed between chronotypes: evening types sustained higher hypothalamic and locus coeruleus BOLD activity in the evening (Schmidt et al. 2009). In addition, a negative correlation was observed with slow-wave-activity-derived sleep pressure levels

and BOLD activity in an anterior hypothalamic region, compatible with the suprachiasmatic area. Follow-up fMRI studies (Schmidt et al. 2015; Schmidt, Peigneux, Leclercq, et al. 2012) further revealed that chronotype × time-of-day effects are observed at the cortical and subcortical level when investigating cognitive control: morning types reduce activation in frontal, cingulate, and thalamic regions from morning to evening hours, while evening types maintain or even increase task-related cortical recruitment, especially under high working-memory load (3 back condition during an N-back working memory task) or for inhibitory processes (Stroop paradigm). Together, this work indicates that brain activity in attention and control networks is modulated by chronotype and time of day—even when behavioural performance appears overtly stable.

The oddball task mimics salience effects and requires the detection of infrequent, target stimuli among frequent non-targets. The task depends on both bottom-up orienting and top-down attentional control, engaging prefrontal and parietal regions (Kim 2014). Because it taxes vigilance over sustained periods, the task may also be sensitive to fatigue-related performance declines (See et al. 1995). This makes it an interesting candidate to examine both synchrony and time-on-task effects. We thus assessed the synchrony effect during a 10-min oddball paradigm in healthy young adults—categorised as extreme morning types or evening types using a chronotype questionnaire (Horne and Ostberg 1976). A within-subjects design was employed such that each participant performed the auditory oddball task in both a morning and an evening session, in a counterbalanced order across participants. Sessions were scheduled to align with habitual and preferred wake and sleep timing of the individual: 1.5 h after scheduled wake-up time for the morning session and 10.5 h after scheduled wake-up time for the evening session.

2 | Methods

2.1 | Participants

Sixteen extreme morning and 15 extreme evening type subjects gave their written informed consent to participate in this study. All volunteers were healthy and between 22 and 32 years of age (morning types: 9 women/7 men; evening types: 8 women/7 men—see also; Schmidt et al. 2015; Schmidt, Peigneux, Leclercq, et al. 2012; Schmidt et al. 2009). Exclusion criteria were reports of medical, psychiatric and sleep disorders, medication or drug use, alcohol abuse, excessive caffeine consumption or physical activity, shift work within the three past months, and transmeridian travel or disturbances in the sleep–wake cycle within 1 month before the experiment. Subjects were screened according to their timing preferences as defined by the morningness–eveningness questionnaire (MEQ, Horne and Ostberg 1976), in which scores > 70 identify extreme morning types and scores < 30 identify extreme evening types. The two groups were matched according to age, biological sex and educational level (morning types: 9w/7m, 24.75 ± 3.9 y.o., 15.75 ± 3 years. of education; evening types: 8w/7m, 23.5 ± 4.1 y.o. 14.98 ± 1.6 years of education). All volunteers fulfilled a written consent form to participate in this study approved by the Ethics Committee of the Faculty of Medicine of the University of Liège and performed in accordance with the ethical standards described in the Declaration of Helsinki (1964).

2.2 | Experimental Procedure

This study was performed between January 2006 and March 2008. Participants were first requested to follow for 1 week the sleep schedule (±30 min) they would spontaneously adopt while free from any socio-professional constraints while averaging their bedtime to 8 h (±1 h). Actimetry (Actiwatch7, Cambridge Neurotechnology, UK) assessed participants' compliance to the selected rest-activity patterns. Afterwards, subjects entered the sleep laboratory for 2 subsequent nights. Participants arrived at the laboratory 7 h before their habitual lights-off time on day 1, after which they were allowed to sleep in the laboratory for 8 h. One and a half (morning session) and 10.5 (evening session) hours after waking up of scheduled sleep timing, subjects underwent an fMRI session during the performance of various cognitive tasks. Seven evening types started with the evening session, while the remaining ($n = 8$) started with the morning session. Similarly, 8 evening types started with the evening session, while the other half started with the morning session. We report here results related to the oddball task; results regarding a psychomotor vigilance task, n-back and Stroop task performance have been reported previously (Schmidt et al. 2015, 2007; Schmidt, Peigneux, Leclercq, et al. 2012). *Oddball task*.

300 auditory stimuli were presented to each participant by a computer-controlled auditory sound system via insert earphones. Stimuli consisted of frequent (600 Hz) and odd tones (400 Hz), presented ~90% and ~10% of the time in a pseudorandomised order. The stimulus duration was 200 msec with an 1800-ms inter-stimulus interval (ISI). Target stimuli (odd tones) were always preceded by at least three standard stimuli (range 3–5). The intervals between stimuli of interest (i.e., target and novel stimuli) were allocated in a pseudo-random manner in the range 6–10 s to ensure that these stimuli had equal probability of occurring at 0, 1, and 2 s after the beginning of a 3-s image-acquisition period. Participants were instructed to press a button with their index as fast and accurately as possible as soon as they heard a target stimulus and were instructed not to respond to a standard or novel stimuli. Reaction times (RTs) were recorded. An analysis of variance (ANOVA) was computed using median reaction times to odd tones as dependent variable and including the factor group (morning vs. evening types) and session (morning vs. evening session) as independent variables. Order of administration (morning-evening vs. evening-morning) was added as a confound variable. Normality was assessed using the Shapiro–Wilk test, which indicated no significant deviation from a normal distribution. In a next step, median RTs were extracted after dividing the 10-min task into three segments of equivalent duration (segment 1, 2, 3). When relevant, association between sleepiness scores and task performance was computed using one-tailed Spearman correlations. For behavioural analysis, p-values were adjusted using the Holm-Bonferroni method to account for multiple comparisons (two separate statistical models).

Unless indicated, statistical inferences were performed at a threshold of $p < 0.05$, using Statistica (StatSoft, 2009, Data analysis software system, version 9.0).

2.3 | MRI Data Acquisition and Analysis

Functional MRI-series (fMRI) were acquired using a head-only 3T scanner (Allegra, Siemens, Germany) while performing the oddball task. Multislice T2*-weighted fMRI images were obtained with a gradient echo-planar sequence using axial slice orientation (TR = 2130 ms, TE = 40 ms, FA = 90°, 32 transverse slices, 3 mm slice thickness, 30% inter-slice gap, FoV = 220 × 220 mm2, matrix size = 64 × 64 × 32, voxel size = (3.4 × 3.4 × 3.0) mm^3). Structural T1-weighted brain images were also acquired (Deichmann et al. 2004). fMRI data from morning and evening sessions were analysed using SPM5 (http://www.fil.ion.ucl.ac.uk) implemented in MATLAB 7 (Mathworks, Sherbom, MA). Volumes were corrected for head motion, spatially normalised, and smoothed. Data were processed using two-step statistical analyses, considering intra-individual then inter-individual variance, respectively. For each subject, brain responses were modelled at each voxel, using a general linear model. Two separate regressors were included: events associated with frequent and rare trials. Linear contrasts tested the main effect of the task (response to odd tones). At the random-effect level, the task-related effect of chronotype [(morning vs. evening types)], of time of day [(morning vs. evening session)] and most importantly the interaction effects between chronotype and time of day [(morning vs. evening session)*(morning vs. evening type)] were tested. The resulting set of voxel values constituted a map of t statistics [SPM(T)] thresholded at $p < 0.001$ (uncorrected; over the whole brain). Statistical inferences were performed after correction for multiple comparisons at a threshold of $p < 0.05$, using Gaussian random field theory at the voxel level in small spherical volumes (radius, 10 mm) around a priori locations of structures of interest, taken from the literature (Andrews-Hanna et al. 2014; Kim 2014).

3 | Results

3.1 | Reaction Times

First, a repeated measures ANOVA revealed no significant main effect of group ($F(1,30) = 0.006$, $p_{adj} > 0.05$, $\eta^2_p = 0.0002$), session ($F(1,30) = 1,68$, $p_{adj} > 0.05$, $\eta^2_p = 0.000214$) or order. In a next step, a separate ANOVA was computed, including the factor time-on-task (segment 1, 2 and 3) as an additional factor. Besides a main effect of time-on-task (increasing RTs with increasing time on task: segment 1 > segment 2 > segment 3: $F(2,60) = 1$, 76, $p_{adj} < 0.05$), this model revealed a significant time-on-task by group interaction ($F(2,60) = 1,98$ $p_{adj} < 0.05$). Inspection of the later indicated that morning types increased more in their reaction times from segment 1/2 to segment 3, when tested in the evening hours and when compared to evening types (Figure 1).

No significant main effect of group ($F(1,30) = 0.006$, $p > 0.05$), nor main effect of session ($F(1,30) = 1,68$, $p_{adj} > 0.05$, $\eta^2_p = 0.000214$), was detected. In a next step, a separate ANOVA was computed, including the factor time-on-task (segment 1, 2 and 3) as an additional factor. Besides a main effect of time-on-task (increasing RTs with increasing time on task: segment 1 > segment 2 > segment 3: $F(2,60) = 3,76$, $p_{adj} < 0.05$, $\eta^2_p = 0.111$), this model revealed a significant time-on-task by group interaction ($F(2,60) = 3,98$, $p_{adj} < 0.05$, $\eta^2_p = 0.117$). Inspection of the later indicated that morning types increased more in their reaction times from segment 1/2 to segment 3, when tested in the evening hours and when compared to evening types (Figure 1). Also, sleepiness scores, as collected by the Karolinska sleepiness scale (KSS, Johns 1991) before task administration, correlated with overall performance of morning types during the evening session ($r = 0,392$, $p < 0.05$), but not with specific task segments, nor during the morning sessions or in evening types.

3.2 | Cerebral Correlates Underlying Oddball Performance According to Time of Day and Chronotype

We observed that BOLD activation in a cluster ($n = 37$ voxels, Figure 2) located in the left inferior frontal cortex (IFC) revealed a significant synchrony effect, with higher activity during the detection of target sounds in the morning than in the evening for morning types, while the reverse pattern was observed in evening types (higher activation in the evening compared to the morning session—Figure 2a,z = 4.01, $p < 0.05$—location

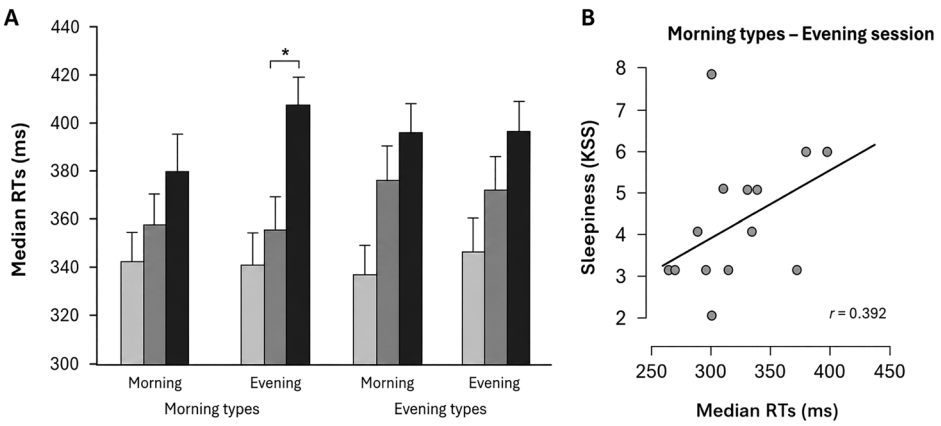

FIGURE 1 | Left panel: Bar plot of median reaction times (RTs) and standard deviations, plotted as a function of session (morning versus evening), chronotype (morning vs. evening type) and task segment (segment 1: Dark grey, segment 2: Light grey, segment 3: Black). The asterisk indicates significantly higher RTs for segment 3, compared to segment 2 in morning types during the evening session. Right panel: Correlation plot between median RTs during the oddball task and subjective sleepiness as assessed with the Karolinska sleepiness scale in morning types during the evening session.

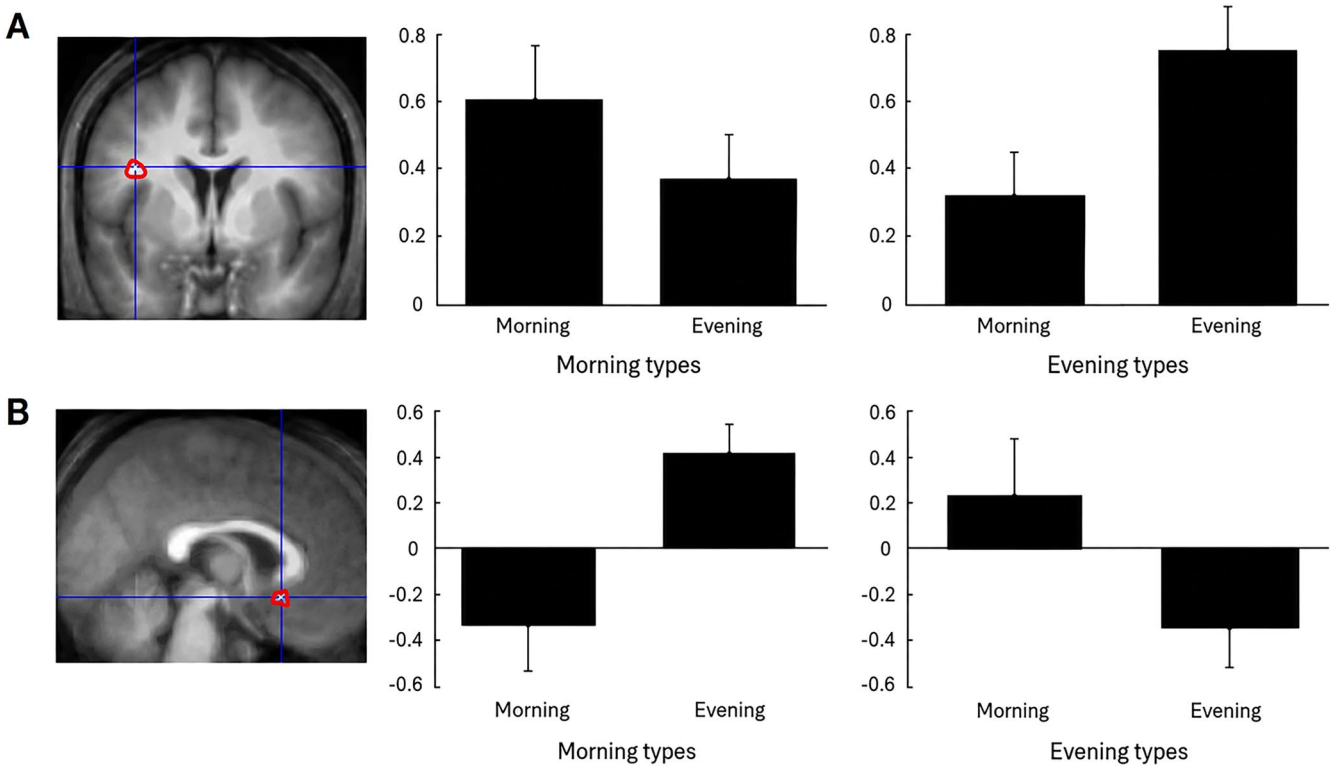

FIGURE 2 | BOLD responses to odd sounds in the (A) inferior frontal cortex and (B) medial orbitofrontal gyrus in morning compared with evening types during morning and evening sessions, respectively. Contrasts are displayed at $p < 0.001$, uncorrected threshold, overlaid on the mean normalised structural MR image of the population. Corresponding parameter estimates are plotted in the right (arbitrary units, mean and standard deviation).

of peak activation: $x = -38$, $y = 2$, $z = 24$—MNI coordinates). Furthermore, BOLD activity in a cluster ($n = 36$ voxels) located in the medial orbitofrontal cortex (mOFC) was more activated in the evening than in the morning in morning chronotypes, while it showed higher activity in the morning than in the evening in evening chronotypes (Figure 2b,$z = 4.35$, $p < 0.05$—location of peak activation: $x = 2$, $y = 20$, $z = -12$—MNI coordinates).

4 | Discussion

We find that task-related brain activation in the IFC is more engaged at optimal times, while activation in the mOFC, part of the default mode network, appears more activated at non-optimal times. At the behavioural level, oddball performance remained globally unaffected by mismatches in time of day and chronotype. However, time-on-task analyses revealed detrimental effects, particularly for morning-type individuals who were tested in the evening.

IFC activation was higher at optimal times (in the morning for morning types, in the evening for evening types). Considering that this region is part of the task-related activation network (Kim 2014), this finding is consistent with the overall idea of a higher engagement to the task at optimal times of the day. BOLD activation in the mOFC lobe, however, showed the opposite pattern. This region is not part of the usually described task-related network but is considered a hub of the default mode network (DMN, e.g., Andrews-Hanna et al. 2010). A higher task-related activation at non-optimal times could indicate intrusion of internally directed processes and reduced attentional engagement. This pattern suggests that at non-optimal times of the day, task-positive networks are under-recruited while the DMN remains active.

From a behavioural point of view, we did not observe significant synchrony effects in reaction times over the whole task. However, when adding a time-on-task component, reaction times subtly increased in the final task segment of the evening session, particularly for morning-type participants. Besides or combined with potential effects of time-awake and circadian phase, this could highlight the impact of fatigue induced by time spent on the task. Time-on-task effects are well documented in sustained attention paradigms (Lim and Dinges 2008) and are commonly interpreted as reflecting the progressive depletion of attentional resources or reduced neural efficiency with continued cognitive effort. Within this context, they may at least partially be attributed to cognitive fatigue that has been suggested as a consequence of sustained cognitive demands irrespective of task complexity (Borragán et al. 2017). Cognitive fatigue can be defined as a decline in performance that develops over a prolonged period of sustained mental effort, as indexed by increases in response times, even when overt accuracy remains relatively preserved. When tested at odd times of the day, morning-type individuals may tend to exhibit earlier performance decline during extended tasks. Under such conditions, fatigue may accumulate more rapidly, leading to greater RT slowing toward the end of the task. This goes in line with previous reports from sustained wakefulness experiments showing that morning types are more vulnerable to time-of-day-related decrements in visual attention and cognitive control compared to evening

types (Barclay and Myachykov 2017). Note that our study was not designed to dissociate between effects of task-induced cognitive fatigue, sleepiness, time awake, or circadian phase. These accounts are indeed conflated in the current design. It is also interesting to note that in this study, sleepiness correlated with overall, rather than segment-specific performance. This may suggest that sleepiness exerts its influence primarily on broad aspects of performance, while segment-level measures may be too variable, compensable, or insensitive to capture these more subtle effects.

Future research should aim to further delineate the interaction between time-on-task-induced effects and chronotype. Critically the number of events (target tones) per segment in the current task setting is low and time-on-task effects should be re-investigated in a setting including more target items per segment (or a longer task duration). Extending paradigms to longer durations and including recovery periods could better capture the dynamic buildup and release of fatigue-related effects. Combining behavioural indices (e.g., RT drift) with electrophysiological markers would further clarify which stages of cognitive processing are most susceptible. Integrating these factors would allow a more nuanced understanding of how sustained cognitive engagement differentially taxes attentional systems across individuals.

Because oddball performance relies on sustained detection of infrequent and salient stimuli, it can be partly translated into daily life contexts as an index of continuous attention monitoring, such as when tracking rare but critical events in occupational, educational, or safety-related settings (e.g., Giraudet et al. 2015). Notably, the synchrony effect has most frequently been assessed at fixed clock times, neglecting individuals' sleep–wake schedules and thus introducing confounds, such as differences in accumulated sleep pressure or circadian phase at test time. Our current findings indicate that subtle behavioural effects and differences in the recruitment of the underlying neuronal correlates persisted even when testing time was adapted to the individual's specific sleep–wake schedule. Within this context, it can be assumed that chronotype represents a phenotypic trait affecting task performance and its underlying cerebral correlates, because results acquired during the biological morning and evening differed despite the same amount of time spent awake and the similar circadian phase across chronotypes. Morning types, for example, may experience faster dissipation of sleep inertia and more rapid accumulation of sleep pressure (Taillard et al. 2003) during the day than evening types. This could result in significant differences in how they cope with oddball performance challenges at different times of day, which manifest as differential neural activation of networks implicated in task engagement and disengagement. Overall, our findings contribute to understanding how time of day and chronotype interact with sustained attention and underscore the relevance of synchrony effects for both basic research and applied domains.

Author Contributions

Fabienne Collette: conceptualization, investigation, funding acquisition, methodology, writing – review and editing, project administration, supervision. **Christian Cajochen:** conceptualization, methodology, writing – review and editing, supervision. **Christina Schmidt:** conceptualization, investigation, writing – original draft, methodology, formal analysis. **Gilles Vandewalle:** conceptualization, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

Andrews-Hanna, J. R., J. S. Reidler, C. Huang, and R. L. Buckner. 2010. "Evidence for the Default Network's Role in Spontaneous Cognition." *Journal of Neurophysiology* 104, no. 1: 322–335. https://doi.org/10.1152/jn.00830.2009.

Andrews-Hanna, J. R., J. Smallwood, and R. N. Spreng. 2014. "The Default Network and Self-Generated Thought: Component Processes, Dynamic Control, and Clinical Relevance." *Annals of the New York Academy of Sciences* 1316, no. 1: 29–52. https://doi.org/10.1111/nyas.12360.

Barclay, N. L., and A. Myachykov. 2017. "Sustained Wakefulness and Visual Attention: Moderation by Chronotype." *Experimental Brain Research* 235, no. 1: 57–68. https://doi.org/10.1007/s00221-016-4772-8.

Borragán, G., H. Slama, M. Bartolomei, and P. Peigneux. 2017. "Cognitive Fatigue: A Time-Based Resource-Sharing Account." *Cortex* 89: 71–84. https://doi.org/10.1016/j.cortex.2017.01.023.

Cajochen, C., and C. Schmidt. 2025. "The Circadian Brain and Cognition." *Annual Review of Psychology* 76, no. 1: 115–141. https://doi.org/10.1146/annurev-psych-022824-043825.

Deichmann, R., C. Schwarzbauer, and R. Turner. 2004. "Optimisation of the 3D MDEFT Sequence for Anatomical Brain Imaging: Technical

Implications at 1.5 and 3 T." *NeuroImage* 21, no. 2: 757–767. https://doi.org/10.1016/j.neuroimage.2003.09.062.

Giraudet, L., M. E. St-Louis, S. Scannella, and M. Causse. 2015. "P300 Event-Related Potential as an Indicator of Inattentional Deafness?" *PLoS One* 10, no. 2: e0118556. https://doi.org/10.1371/journal.pone.0118556.

Hasher, L., D. Goldstein, and C. P. May. 2005. "It's About Time: Circadian Rhythms, Memory, and Aging." In *Human Learning and Memory: Advances in Theory and Application*, edited by C. Izawa and N. Ohta, 199–217. Lawrence Erlbaum Associates.

Horne, J. A., and O. Ostberg. 1976. "A Self-Assessment Questionnaire to Determine Morningness-Eveningness in Human Circadian Rhythms." *International Journal of Chronobiology* 4, no. 2: 97–110.

Johns, M. W. 1991. "A New Method for Measuring Daytime Sleepiness: The Epworth Sleepiness Scale." *Sleep* 14, no. 6: 540. https://doi.org/10.1093/sleep/14.6.540.

Kim, H. 2014. "Involvement of the Dorsal and Ventral Attention Networks in Oddball Stimulus Processing: A Meta-Analysis." *Human Brain Mapping* 35, no. 5: 2265–2284. https://doi.org/10.1002/hbm.22326.

Lim, J., and D. F. Dinges. 2008. "Sleep Deprivation and Vigilant Attention." *Annals of the New York Academy of Sciences* 1129: 305–322. https://doi.org/10.1196/annals.1417.002.

May, C. P. 1999. "Synchrony Effects in Cognition: The Costs and a Benefit." *Psychonomic Bulletin & Review* 6, no. 1: 142–147. https://doi.org/10.3758/bf03210822.

May, C. P., L. Hasher, and K. Healey. 2023. "For Whom (And When) the Time Bell Tolls: Chronotypes and the Synchrony Effect." *Perspectives on Psychological Science* 18, no. 6: 1520–1536. https://doi.org/10.1177/17456916231178553.

Roenneberg, T., and M. Merrow. 2007. "Entrainment of the Human Circadian Clock." *Cold Spring Harbor Symposia on Quantitative Biology* 72: 293–299. https://doi.org/10.1101/sqb.2007.72.043.

Schmidt, C., F. Collette, C. Cajochen, and P. Peigneux. 2007. "A Time to Think: Circadian Rhythms in Human Cognition." *Cognitive Neuropsychology* 24, no. 7: 755–789. https://doi.org/10.1080/02643290701754158.

Schmidt, C., F. Collette, Y. Leclercq, et al. 2009. "Homeostatic Sleep Pressure and Responses to Sustained Attention in the Suprachiasmatic Area." *Science* 324, no. 5926: 516–519. https://doi.org/10.1126/science.1167337.

Schmidt, C., F. Collette, C. F. Reichert, et al. 2015. "Pushing the Limits: Chronotype and Time of Day Modulate Working Memory-Dependent Cerebral Activity." *Frontiers in Neurology* 25, no. 6: 199. https://doi.org/10.3389/fneur.2015.00199.

Schmidt, C., P. Peigneux, C. Cajochen, and F. Collette. 2012. "Adapting Test Timing to the Sleep-Wake Schedule: Effects on Diurnal Neurobehavioral Performance Changes in Young Evening and Older Morning Chronotypes." *Chronobiology International* 29, no. 4: 482–490. https://doi.org/10.3109/07420528.2012.658984.

Schmidt, C., P. Peigneux, Y. Leclercq, et al. 2012. "Circadian Preference Modulates the Neural Substrate of Conflict Processing Across the Day." *PLoS One* 7, no. 1: e29658. https://doi.org/10.1371/journal.pone.0029658.

See, J. E., S. R. Howe, J. S. Warm, and W. N. Dember. 1995. "Meta-Analysis of the Sensitivity Decrement in Vigilance." *Psychological Bulletin* 117, no. 2: 230. https://doi.org/10.1037/0033-2909.117.2.230.

Taillard, J., P. Philip, O. Coste, P. Sagaspe, and B. Bioulac. 2003. "The Circadian and Homeostatic Modulation of Sleep Pressure During Wakefulness Differs Between Morning and Evening Chronotypes." *Journal of Sleep Research* 12, no. 4: 275–282. https://doi.org/10.1046/j.0962-1105.2003.00369.x.

Yoon, C., C. P. May, and L. Hasher. 2000. "Aging, Circadian Arousal Patterns, and Cognition." In *Cognitive Aging*, edited by N. Schwarz, D. Park, B. Knauper, and S. Sudman, 117–143. Psychology Press.