

Supporting Information

Relationship between circadian rhythm and brain cognitive functions

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Table S1 Selected articles in this review

authors	year	methods	components	main discoveries/contributions
Laird Donald A.	1925	behavior	working memory	The output of working memory was at its highest on Wednesday, steadily reaching the high point on this day and suddenly falling to a very low level on the day following. Many of the individual measures followed this curve of rising and fall in general.
M. J. F. Blake	1967	behavior	working memory	Findings show that, as shown by body temperature, the working memory is related to the underlying state of arousal.
S Folkard	1975	behavior	working memory	The study indicates that the greater the short-term memory portion of a mission, the higher the output peaks earlier in the day.
Hartley L. , R. Shirley E.	1976	behavior	high-order cognitive functions	
Simon Folkard	1979	behavior	working memory	Subjects can rely more on working memory processing in the morning, but more on elaborate processing in the evening.

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S W Johnson , R A North	1992	behavior	cognitive performance	Hyperpolarization of opioid interneurons is concluded to decrease the random feedback synaptic of the GABA to cells of dopamine. This in vivo will lead to the disinhibition of dopamine cells that would contribute to the beneficial strengthening of mu-receptor agonists like morphine and heroin.
S Shinkai , S Watanabe , Y Kurokawa , J Torii	1993	behavior	cognitive conflicts	Salivary cortisol appears to be an excellent measure for monitoring circadian rhythm variation in adrenal activity in healthy individuals during shiftwork.
A Baddeley	1996	behavior	short-term memory, long-term memory	The model used in this research has proven to be long lasting and useful and is ready to map recent neuroanatomical advances through the development of electrophysiological and positive emission tomographic scan measures.
D F Dinges , F Pack, K Williams , K A Gillen , J W Powell , G E Ott , C Aptowicz , A I Pack	1997	behavior	tonic alertness, selective attention, sustained attention	Sleep restriction resulted in statistically robust cumulative effects on waking functions. Time-of-day effects were evident in subjective sleepiness and psychomotor vigilance data. Recovery from sleep deficits appeared to require two full nights of sleep.
M E McCarthy , W F Waters	1997	behavior	tonic alertness, selective attention, sustained attention	Discoveries demonstrate deficit of attention, the first shows a sluggish turn of attention to novel stimuli, the second shows a lower allocation of attention to stimuli and the third shows a faster loss of attention to repetitive stimuli. In the decreased cognitive function observed during sleep loss, these phenomena may be caused.

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M. Gillberg , T. Åkerstedt	1998	behavior	tonic alertness, selective attention, sustained attention	The capacity to maintain vigilance falls with time on task.
Edward Awh , john Jonides , Edward E. Smith , Richard B. Buxton , Larry R. Frank , Tracy Love , Eric C. Wong , Leon Gmeindl	1999	fMRI	prefrontal cortex activation	In the early visual fields, spatial rehearsals led to expanded stimulation contralateral to the sites memorized.
Cynthia P. May	1999	behavior	cognitive association	The creativity research revealed that creativity itself does not consist of the association's circadian propensity.
J Carrier , T H Monk	2000	behavior	cognitive performance	This research briefly introduces recent statistical alert models used for cognitive output estimation. Themes are presented, including interindividual discrepancies and post-lunch dip.
K Vedhara , J Hyde , I D Gilchrist , M Tytherleigh , S Plummer	2000	behavior	working memory	The conclusion indicates that the findings support the opinion that cortisol can modulate cognitive processes and that corticosteroids have selective effects on cognitive function.
W Sturm , K Willmes	2001	fMRI	phasic alertness	There are additional activations of left-hemisphere frontal and parietal structures during phasic alertness conditions that are perceived as basal features of attention selectivity rather than additional alerting characteristics.
L De Gennaro , M Ferrara, G Curcio , M Bertini	2001	behavior	attention	In the visual search task, it is concluded that 40 h of prolonged wakefulness significantly impairs efficiency. Such an impairment is obvious for speed, but not for accuracy indicators, and is strictly linked to the impairment of the motor oculum, suggesting a distinct circadian effect.
S P Drummond , G G Brown	2001	fMRI	working memory	Increased sleepiness following sleep deprivation and lower levels of working memory impairment were associated with

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				increased activation in particular regions of the prefrontal cortex and parietal lobes, respectively.
C E Stern , S J Sherman , B A Kirchhoff , M E Hasselmo	2001	fMRI	working memory	Results are consistent with previous animal study, and indicating that for tracking and matching common stimuli with a high propensity for intervention, prefrontal regions may be essential, while media temporal regions may be increasing in proportion to matching and sustaining new stimuli.
Kenneth P Wright Jr , Joseph T Hull , Charles A Czeisler	2002	behavior	cognitive performance	The findings support a hypothesis which shows that human neuroscience modulates body temperature.
Tom Manly , Geraint H Lewis , Ian H Robertson , Peter C Watson , Avijit K Datta	2002	behavior	sustained attention to response	The circadian cycle differentially affects different brain regions and connections between sleep loss and normal dysexecutive behavior can prove a useful additional approach in this field by analyzing variance across the course of the day.
Anne Bonnefond , Odile Rohmer , Alain Hoeft , Alain Muzet , Patricia Tassi	2003	behavior	attention	The study has found that the age influence is subject to everyday time with only the more complicated activity requiring attention and storage. Apart from juniors, a simple mission did not sacrifice productivity. Senior citizens.
Herbert Heuer , Thomas Kleinsorge , Wolfhard Klein , Olaf Kohlisch	2004	behavior	task switching	The results indicate that overall sleep deprivation increases and hence lapses in task set volatility, in particular under circumstances where there are long stimulation intervals and in shift studies. Moreover, the length of an exogenously regulated mechanism involved in extradimensional transitions tends to maximize cumulative sleep deprivation.
Peter Graw , Kurt Kräuchi , Vera Knoblauch , Anna Wirz-Justice , Christian Cajochen	2004	behavior	tonic alertness	This research shows a specific sensitivity to detect very soon results of increasing sleep pressure from the disparity between quickest and slowest response time. However, reductions in the

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				efficiency of psychomotor surveillance activities related to the circadian process were not substantially depended on any kind of categorisation.
Michael W L Chee , Wei Chieh Choo	2004	behavior	working memory	Findings provide neuronal associations to understand why task output in comparatively more complicated tasks is best maintained compared to simpler tasks following sleep deprivation.
Valdez , Pablo Ramírez , Candelaria García , Aída Talamantes, Javier Armijo , Pablo Borrani , Jorge	2005	behavior	attention	Circadian differences in these elements of attention can be vital to the success of certain tasks, such as memory, reading, computing arithmetic, etc. A close correlation between this component and fatigue is indicated by the dissociation of vigilance from the other focus elements. In order to minimize efficiency and raise the risk of injuries during night shift work, circadian fluctuations in attention components are also important.
Wei-Chieh Choo , Wei-Wei Lee , Vinod Venkatraman , Fwu-Shan Sheu , Michael W L Chee	2005	fMRI	working memory	Study results are a step in understanding how various brain areas show differing vulnerabilities to the deleterious effects of sleep loss on working memory.
Qiwen Mu , Alexander Mishory , Kevin A Johnson , Ziad Nahas , Frank A Kozel , Kaori Yamanaka , Daryl E Bohning , Mark S George	2005	fMRI	working memory	Preliminary findings indicate that levels of brain activity during the Sternberg work-memory task at the resting baseline and sleep-deprivation state vary between individuals as a result of their sleep-deprivation susceptibility.
Patricia Sagaspe , Montserrat Sanchez-Ortuno , André Charles, Jacques Taillard , Cédric Valtat , Bernard Bioulac , Pierre Philip	2006	behavior	cognitive conflict	It has been concluded that 36 hours of extended awakesness affect self-reported anxiety and cognitive latency. In comparison, complete sleep loss in each of the three short stop activities has little effect on disturbance control.

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Michael W L Chee , Lisa Y M Chuah , Vinod Venkatraman , Wai Yen Chan , Pierre Philip , David F Dinges	2006	behavior	working memory	After normal sleep, stimulation of the left parietal and left frontal regions was negatively associated with a reduction in output accuracy from normal sleep, thereby differentiating individuals who retained working memory performance from those who were vulnerable to its effects after sleep deprivation.
Julian Lim , Wei-Chieh Choo , Michael W L Chee	2007	fMRI	working memory	The neural basis for these differences has yet to be uncovered. This study assessed the reproducibility of fMRI activation and performance on a working memory task before and after 24 hours of sleep deprivation
Yvonne Harrison , Kay Jones , Jim Waterhouse	2007	behavior	inhibition task	The wake period had an impact on this mission, but no circadian portion for inhibitory efficiency. An interaction indicated that success varied depending on the duration of previous wakefulness, coinciding with the rising arm of the circadian period.
Julian Lim , David F Dinges	2008	behavior	attention	The effects of the relationship between "top-down" and "bottom-up" attention in inducing erratic and volatile behavioral behaviors are the characteristic of the sleep-deprived state.
Y L Chee , J C Crawford , H G Watson , M Greaves	2008	fMRI	endogenous attention	This study explored the endogenous attention ability under sleep deprivation and suggested the decrease of the frontal-parietal top-down control concerning attention and the extrastriate visual cortex process
Gillian Rowe , Lynn Hasher , Josée Turcotte	2009	behavior	visuospatial working memory	This study indicates that both time and interference testing play a critical role in determining age differences in the length of visuospatial working memory, and it could be important to minimize interference and peak-time testing to enhance the

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				output of older adults and to increase the decrease of age differences.
Robert L Matchock , J Toby Mordkoff	2009	behavior	selective attention	The peak of selective attention is recognized to be increased around midday
D Tomasi , R L Wang , F Telang, V Boronikolas , M C Jayne , G-J Wang , J S Fowler , N D Volkow	2009	fMRI	attention	The decreased activation in parietal and blunted deactivation in the cingulate cortices may be triggered by Thalamic Hyperactivation during sleep deprivation which would disrupt the attentive network necessary to the correct visuals-spatial focus.
Daniel Bratzke , Bettina Rolke , Michael B Steinborn , Rolf Ulrich	2009	behavior	task switching	Sleep deprivation and circadian influences the ability of the current task to plan unrelated stimulus information rather than the automated processing.
Pablo Valdez , Candelaria Ramírez , Aída García , Javier Talamantes , Juventino Cortez	2010	behavior	sustained attention	Results show that at the conclusion of a transition, efficiency at work deteriorates due to a reduction in overall stability, an increase in error runs, a decrease in long-hit runs, and a decrease in job time. Due to a decline in overall stability and a rise in error runs, night shift workers are subject to further degradation inefficiency during the overnight.
Jason R Gerstner 1, Jerry C P Yin	2010	behavior	long-term memory	Findings indicate that circadian rhythmicity and long-term memory development are underlying typical mechanisms.
Motoyasu Honma , Takahiro Soshi , Yoshiharu Kim , Kenichi Kuriyama	2010	fMRI	working memory	Characteristics of the capacity to transcend sleepiness during the task of n-back working memory, which goes beyond the usually suggested attention-control function.

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Takahiro Soshi,Kenichi Kuriyama ,Sayaka Aritake,Minori Enomoto,Akiko Hida,Miyuki Tamura,Yoshiharu Kim,Kazuo Mishima	2010	fNIRS	short-time perception	Findings imply that the activation of the left PFC, which may represent functional compensation in a sleep-deprived state, is correlated with a shift in the perception of the short time.
Michael W L Chee , Cindy S F Goh , Praneeth Namburi , Sarayu Parimal , Katharina N Seidl , Sabine Kastner	2011	behavior	visuospatial attention	Sleep deprivation was unlike the duration of the preparatory period, which suggested a decreased amount of but still functional circuits during sleep deprivation through regulation of stimulus-evoked activation by attention.
Mareike Wieth , Rose T. Zacks	2011	behavior	cognitive association	Findings suggest that a non-optimal time of day may benefit from activities requiring imagination.
Jack A De Havas , Sarayu Parimal , Chun Siong Soon , Michael W L Chee	2012	fMRI	attention	Sleep deprivation was associated with major selective decreases in the functional connectivity of the default network mode (DMN).
Benjamin S.McKenna , Lisa T.Eyler	2012	behavior	bipolar disorder	Bipolar disorder and its defects in the prefrontal cortex have indicated that this mechanism can include sleep and circadian cycles, possibly meaning that working memory capacity has been damaged.
Daniel Bratzke , Michael B Steinborn , Bettina Rolke , Rolf Ulrich	2012	behavior	executive functions	The present findings contradict the widespread belief that executive functions are highly vulnerable to the effects of sleep deprivation and circadian rhythm.

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Christina Schmidt , Philippe Peigneux , Yves Leclercq , Virginie Sterpenich , Gilles Vandewalle , Christophe Phillips , Pierre Berthomier , Christian Berthomier , Gilberte Tinguely , Steffen Gais , Manuel Schabus , Martin Desseilles , Thanh Dang-Vu , Eric Salmon , Christian Degueldre , Evelyne Balteau , André Luxen , Christian Cajochen , Pierre Maquet , Fabienne Collette	2012	fMRI	higher-order cognitive state	Findings shed light on the cerebral mechanisms that affect inter-individual variations in management of the higher-order cognitive process under typical day-night conditions.
Candelaria Ramírez , Aída García , Pablo Valdez	2012	behavior	cognitive switching	Circadian differences in two management components: inhibition and versatility, modulated by a continuous concentration.
Ronald A. Cohen	2013	behavior	working memory	This study indicates that both time and interference testing play a critical role in determining age differences in the length of visuospatial working memory, and it could be important to minimize interference and peak-time testing to enhance the output of older adults and to increase the decrease of age differences.
Sean P A Drummond , Matthew Walker , Erin Almklov , Manuel Campos , Dane E Anderson , Laura D Straus	2013	fMRI	working memory	This study establishes a profile of abnormal neural function in primary insomnia. This is reflected in the reduced engagement of task-appropriate brain regions and an inability to modulate task-irrelevant areas

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Benjamin S McKenna , Ashley N Sutherland , Anna P Legenkaya , Lisa T Eyer	2014	fMRI	working memory	In patients with bipolar disorder, a decrease in activation during the encoding interval shows that attention deficits are at the center of working memory deficits. Such deficits tend to be trait-like in that they have been observed in patients with bipolar disorder during times of euthymia.
Clare Nicholls , Raimondo Bruno , Allison Matthews	2015	behavior	diurnal variations, visuospatial attention	The research indicates variations in inhibitor care within the executive function network between chronic cannabis patients and monitors and may include the right inferior cortex in the front. It also indicates discrepancies between chronic cannabis patients and controls and may include the right inferior frontal cortex in terms of inhibitory processing within the executive control network.
Harini C. Krishnan , Lisa C. Lyons	2015	behavior	cognitive conflict	This survey discusses the relationship forms by which circadian clocks modulate cognition, reveals advances in the recognition of mechanistic associations between the circadian system and memory systems, describes approaches used to repair circadian disruptions, and enhances circadian adaptation.
Stephanie M Sherman , Jeanette A Mumford , David M Schnyer	2015	fMRI	creativity	The creativity research revealed that creativity itself does not consist of the association's circadian propensity.
Vincenzo Muto , Mathieu Jaspard , Christelle Meyer , Caroline Kussé , Sarah L Chellappa , Christian Degueldre , Evelyne Balteau , Anahita Shaffii-Le Bourdieu , André Luxen , Benita Middleton , Simon N Archer , Christophe Phillips , Fabienne	2016	behavior	cognitive conflict	Findings extend the current understanding of the processes involved in preserving cognition during the day and its degradation during sleep loss and circadian misalignment.

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Collette , Gilles Vandewalle , Derk-Jan Dijk , Pierre Maquet				
Matthew Riley	2017	behavior	attention	This research found that between 9:00 a.m., the ability to maintain concentration could improve to a high level. Then 11:00 a.m., and then decreases later.
Koryna Lewandowska , Barbara Wachowicz , Tadeusz Marek , Halszka Oginska , Magdalena Fafrowicz	2017	behavior	decision process	Diurnal variations in the production of norepinephrine have an effect on the perceptual processing of the judgment threshold.
Aleksandra Domagalik , Halszka Oginska , Ewa Beldzik , Magdalena Fafrowicz , Malgorzata Pokrywka , Piotr Chaniecki , Marek Rekas , Tadeusz Marek	2019	behavior	visuospatial working memory	Results offer evidence that excessive reduction of blue light sensitivity directly influences human cognitive functioning independently of the circadian rhythm.