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Catecholamine function, brain state dynamics, and human cognition

Brink, R.L. van den

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Author: Van den Brink R.L.

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8. References

- Achard S, Bullmore E (2007) Efficiency and cost of economical brain functional networks. *PLoS Comput Biol* 3:e17.
- Akaike H (1974) New look at statistical-model identification. *IEEE Trans Automat Contr Ac* 19:716–723.
- Allen EA, Damaraju E, Plis SM, Erhardt EB, Eichele T, Calhoun VD (2014) Tracking whole-brain connectivity dynamics in the resting state. *Cereb Cortex* 24:663–676.
- Andrews K (1996) International Working Party on the Management of the Vegetative State: summary report. *Brain Injury* 10:797–806.
- Aston-Jones G, Bloom FE (1981) Activity of the norepinephrine-containing locus coeruleus neurons in behaving rats anticipates fluctuations in the sleep-waking cycle. *J Neurosci* 1:876–886.
- Aston-Jones G, Cohen JD (2005) An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annu Rev Neurosci* 28:403–450.
- Aston-Jones G, Foote SL, Bloom FE (1984) Anatomy and physiology of locus coeruleus neurons: Functional implications. In: Norepinephrine (Ziegler MG, Lake CR, eds), pp 92–116. Baltimore: Williams & Wilkins.
- Bagnato S, Boccagni C, Sant'angelo A, Fingelkurts AA, Fingelkurts AA, Galardi G (2013) Emerging from an unresponsive wakefulness syndrome: brain plasticity has to cross a threshold level. *Neuroscience and biobehavioral reviews* 37:2721–2736.
- Bargmann CI, Marder E (2013) From the connectome to brain function. *Nature Methods* 10:483–490.
- Barttfeld P, Uhrig L, Sitt JD, Sigman M, Jarraya B, Dehaene S (2015) Signature of consciousness in the dynamics of resting-state brain activity. *Proc Natl Acad Sci USA* 112:887–892.
- Beatty J (1982) Task-evoked pupillary responses, processing load, and the structure of processing resources. *Psychological Bulletin* 91:276–292.
- Beckmann CF (2009) Group comparison of resting-state fMRI data using multi-subject ICA and dual regression. *OHBM*.
- Berens P (2009) CircStat: A MATLAB toolbox for circular statistics. *Journal of statistics software* 31:1–21.
- Berridge CW, Waterhouse BD (2003) The locus coeruleus–noradrenergic system: modulation of behavioral state and state-dependent cognitive processes. *Brain Research Reviews* 42:33–84.
- Besle J, Schevon CA, Mehta AD, Lakatos P, Goodman RR, McKhann GM, Emerson RG, Schroeder CE (2011a) Tuning of the human neocortex to the temporal dynamics of attended events. *J Neurosci* 31:3176–3185.
- Besle J, Schevon CA, Mehta AD, Lakatos P, Goodman RR, McKhann GM, Emerson RG, Schroeder CE (2011b) Tuning of the human neocortex to the temporal dynamics of attended events. *The Journal of Neuroscience* 31:3176–3185.
- Biswal B, Yetkin FZ, Haughton VM, Hyde JS (1995) Functional connectivity in the motor cortex of resting human brain using echo-planar MRI. *Magn Reson Med* 34:537–541.
- Blondel VD, Guillaume J-L, Lambiotte R, Lefebvre E (2008) Fast unfolding of communities in large networks. *J Stat Mech: Theory and Experiment*.
- Boly M, Garrido MI, Gosseries O, Bruno MA, Boveroux P, Schnakers C, Massimini M, Litvak V, Laureys S, Friston K (2011) Preserved feedforward but impaired top-down processes in the vegetative state. *Science* 332:858–862.

- Botvinick MM, Braver TS, Barch DM, Carter CS, Cohen JD (2001) Conflict monitoring and cognitive control. *Psychological Review* 108:624-652.
- Bouret S, Sara SJ (2005) Network reset: a simplified overarching theory of locus coeruleus noradrenaline function. *Trends in neurosciences* 28:574-582.
- Brown SB, Tona KD, van Noorden MS, Giltay EJ, van der Wee NJ, Nieuwenhuis S (2015) Noradrenergic and cholinergic effects on speed and sensitivity measures of phasic alerting. *Behavioral neuroscience* 129:42-49.
- Bullmore E, Sporns O (2009) Complex brain networks: Graph theoretical analysis of structural and functional systems. *Nat Rev Neurosci* 10:186-198.
- Bymaster FP, Katner JS, Nelson DL, Hemrick-luecke SK, Threlkeld PG, Heiligenstein JH, Mroin SM, Gehlert DR, Perry KW (2002) Atomoxetine increases extracellular levels of norepinephrine and dopamine in prefrontal cortex of rat: A potential mechanism for efficacy in attention deficit/hyperactivity disorder. *Neuropsychopharmacol* 27.
- Casali AG, Gosseries O, Rosanova M, Boly M, Simone Sarasso, Casali KR, Casarotto S, Bruno M-A, Laureys S, Tononi G, Massimini M (2013) A Theoretically Based Index of Consciousness Independent of Sensory Processing and Behavior. *Science Translational Medicine* 5:198ra105.
- Cavanagh JF, Cohen MX, Allen JJ (2009a) Prelude to and resolution of an error: EEG phase synchrony reveals cognitive control dynamics during action monitoring. *J Neurosci* 29:98-105.
- Cavanagh JF, Cohen MX, Allen JJ (2009b) Prelude to and resolution of an error: EEG phase synchrony reveals cognitive control dynamics during action monitoring. *The Journal of Neuroscience* 29:98-105.
- Chamberlain SR, Muller U, Blackwell AD, Robbins TW, Sahakian BJ (2006a) Noradrenergic modulation of working memory and emotional memory in humans. *Psychopharmacology* 188:397-407.
- Chamberlain SR, Müller U, Blackwell AD, Clark L, Robbins TW, Sahakian BJ (2006b) Neurochemical Modulation of Response Inhibition and Probabilistic Learning in Humans. *Science* 311:861-863.
- Chamberlain SR, Del Campo N, Dowson J, Muller U, Clark L, Robbins TW, Sahakian BJ (2007) Atomoxetine improved response inhibition in adults with attention deficit/hyperactivity disorder. *Biol Psychiatry* 62:977-984.
- Chandler DJ, Gao W-J, Waterhouse BD (2014) Heterogeneous organization of the locus coeruleus projections to prefrontal and motor cortices. *Proc Natl Acad Sci U S A* 111:6816-6821.
- Cheadle S, Wyart V, Tsetsos K, Myers N, de Gardelle V, Herce Castanon S, Summerfield C (2014) Adaptive gain control during human perceptual choice. *Neuron* 81:1429-1441.
- Chennu S, Finoia P, Kamau E, Allanson J, Williams GB, Monti MM, Noreika V, Arnatkeviciute A, Canales-Johnson A, Olivares F, Cabezas-Soto D, Menon DK, Pickard JD, Owen AM, Bekinschtein TA (2014) Spectral signatures of reorganised brain networks in disorders of consciousness. *PLoS Comput Biol* 10:e1003887.
- Cohen JD, Botvinick MM, Carter CS (2000) Anterior cingulate and prefrontal cortex: who's in control? *Nat Neurosci* 3:421-423.
- Cohen M (2014a) *Analyzing neural time series data: theory and practice*. Cambridge, MA: MIT.
- Cohen MX (2014b) *Analyzing neural time series data: theory and practice*. MIT Press.

- Cohen MX, van Gaal S, Ridderinkhof KR, Lamme VA (2009) Unconscious errors enhance prefrontal-occipital oscillatory synchrony. *Frontiers in human neuroscience* 3:54.
- Cohen MX, Bour L, Mantione M, Figee M, Vink M, Tijssen MA, van Rootselaar AF, van den Munckhof P, Schuurman PR, Denys D (2012) Top-down-directed synchrony from medial frontal cortex to nucleus accumbens during reward anticipation. *Hum Brain Mapp* 33:246-252.
- Cole DM, Beckmann CF, Oei NY, Both S, van Gerven JM, Rombouts SA (2013) Differential and distributed effects of dopamine neuromodulations on resting-state network connectivity. *Neuroimage* 78:59-67.
- Cole MW, Ito T, Bassett DS, Schultz DH (2016) Activity flow over resting-state networks shapes cognitive task activations. *Nat Neurosci* 19:1718-1726.
- Colzato LS, de Rover M, van den Wildenberg WP, Nieuwenhuis S (2013) Genetic marker of norepinephrine synthesis predicts individual differences in post-error slowing: A pilot study. *Neuropsychologia*.
- Corbetta M, Shulman GL (2002) Control of goal-directed and stimulus-driven attention in the brain. *Nat Rev Neurosci* 3:201-215.
- Corbetta M, Patel G, Shulman GL (2008) The reorienting system of the human brain: from environment to theory of mind. *Neuron* 58:306-324.
- Coull JT, Middleton HC, Robbins TW, Sahakian BJ (1995) Clonidine and diazepam have differential effects on tests of attention and learning. *Psychopharmacology* 120:322-331.
- Coull JT, Büchel C, Friston KJ, Firth CD (1999) Noradrenergically mediated plasticity in a human attentional neuronal network. *Neuroimage* 10:705-715.
- Craddock RC, James GA, Holtzheimer PE, 3rd, Hu XP, Mayberg HS (2012) A whole brain fMRI atlas generated via spatially constrained spectral clustering. *Hum Brain Mapp* 33:1914-1928.
- Cravo AM, Rohenkohl G, Wyart V, Nobre AC (2013) Temporal expectation enhances contrast sensitivity by phase entrainment of low-frequency oscillations in visual cortex. *The Journal of Neuroscience* 33:4002-4010.
- Crochet S, Petersen CC (2006) Correlating whisker behavior with membrane potential in barrel cortex of awake mice. *Nat Neurosci* 9:608-610.
- Dang-Vu TT, Schabus M, Desseilles M, Albouy G, Boly M, Darsaud A, Gais S, Rauchs G, Sterpenich V, Vandewalle G, Carrier J, Moonen G, Balteau E, Degueldre C, Luxen A, Phillips C, Maquet P (2008) Spontaneous neural activity during human slow wave sleep. *Proc Natl Acad Sci U S A* 105:15160-15165.
- Danielmeier C, Ullsperger M (2011) Post-error adjustments. *Frontiers in psychology* 2:233.
- Danielmeier C, Eichele T, Forstmann BU, Tittgemeyer M, Ullsperger M (2011) Posterior medial frontal cortex activity predicts post-error adaptations in task-related visual and motor areas. *The Journal of Neuroscience* 31:1780-1789.
- Dayan P, Yu AJ (2006) Phasic norepinephrine: a neural interrupt signal for unexpected events. *Network: Computation in Neural Systems* 17:335-350.
- de Gee JW, Colizoli O, Kloosterman NA, Knapen T, Nieuwenhuis S, Donner T (2017) Dynamic modulation of decision biases by brainstem arousal systems. *eLife* 6:e23232.
- De Luca M, Smith S, De Stefano N, Federico A, Matthews PM (2005) Blood oxygenation level dependent contrast resting state networks are relevant to functional activity in the neocortical sensorimotor system. *Exp Brain Res* 167:587-594.

- deBettencourt MT, Cohen JD, Lee RF, Norman KA, Turk-Browne NB (2015) Closed-loop training of attention with real-time brain imaging. *Nat Neurosci* 18:470-475.
- Deco G, Jirsa VK, McIntosh AR (2011) Emerging concepts for the dynamical organization of resting-state activity in the brain. *Nat Rev Neurosci* 12:43-56.
- Deco G, Ponce-Alvarez A, Mantini D, Romani GL, Hagmann P, Corbetta M (2013) Resting-state functional connectivity emerges from structurally and dynamically shaped slow linear fluctuations. *J Neurosci* 33:11239-11252.
- Delorme A, Makeig S (2004a) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *The Journal of Neuroscience Methods* 134:9-21.
- Delorme A, Makeig S (2004b) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *J Neurosci Methods* 134:9-21.
- Demertzi A, Antonopoulos G, Heine L, Voss HU, Crone JS, de Los Angeles C, Bahri MA, Di Perri C, Vanhaudenhuyse A, Charland-Verville V, Kronbichler M, Trinka E, Phillips C, Gomez F, Tshibanda L, Soddu A, Schiff ND, Whitfield-Gabrieli S, Laureys S (2015) Intrinsic functional connectivity differentiates minimally conscious from unresponsive patients. *Brain : a journal of neurology* 138:2619-2631.
- Devoto P, Flore G (2006) On the origin of cortical dopamine: Is it a co-transmitter in noradrenergic neurons? *Curr Neuroparmacol* 4:115-125.
- Devoto P, Flore G, Pira L, Longu G, Gessa GL (2004) Alpha2-adrenoceptor mediated co-release of dopamine and noradrenaline from noradrenergic neurons in the cerebral cortex. *J Neurochem* 88:1003-1009.
- Di Perri C, Bahri MA, Amico E, Thibaut A, Heine L, Antonopoulos G, Charland-Verville V, Wannez S, Gomez F, Hustinx R, Tshibanda L, Demertzi A, Soddu A, Laureys S (2016) Neural correlates of consciousness in patients who have emerged from a minimally conscious state: a cross-sectional multimodal imaging study. *The Lancet Neurology* 15:830-842.
- Dimigen O, Sommer W, Hohnsbein A, Jacobs AM, Kliegl R (2011) Coregistration of eye movements and EEG in natural reading: analyses and review. *Journal of experimental psychology General* 140:552-572.
- Donner TH, Siegel M (2011) A framework for local cortical oscillation patterns. *Trends in cognitive sciences* 15:191-199.
- Donner TH, Nieuwenhuis S (2013) Brain-wide gain modulation: the rich get richer. *Nat Neurosci* 16:989-990.
- Donner TH, Sagi D, Bonneh YS, Heeger DJ (2013) Retinotopic patterns of correlated fluctuations in visual cortex reflect the dynamics of spontaneous perceptual suppression. *J Neurosci* 33:2188-2198.
- Drew PJ, Duyn JH, Golanov E, Kleinfeld D (2008) Finding coherence in spontaneous oscillations. *Nat Neurosci* 11:991.
- Dudschig C, Jentsch I (2009) Speeding before and slowing after errors: is it all just strategy? *Brain Research* 1296:56-62.
- Dutilh G, Vandekerckhove J, Forstmann BU, Keuleers E, Brysbaert M, Wagenmakers EJ (2012a) Testing theories of post-error slowing. *Attention, perception & psychophysics* 74:454-465.
- Dutilh G, van Ravenzwaaij D, Nieuwenhuis S, van der Maas HLJ, Forstmann BU, Wagenmakers E-J (2012b) How to measure post-error slowing: A confound and a simple solution. *Journal of Mathematical Psychology* 56:208-216.

- Eichele H, Juvodden HT, Ullsperger M, Eichele T (2010) Mal-adaptation of event-related EEG responses preceding performance errors. *Frontiers in human neuroscience* 4.
- Eilander HJ, Wijnen VJ, Scheirs JG, de Kort PL, Prevo AJ (2005) Children and young adults in a prolonged unconscious state due to severe brain injury: outcome after an early intensive neurorehabilitation programme. *Brain Injury* 19:425-436.
- Eilander HJ, van de Wiel M, Wijers M, van Heugten CM, Buljevac D, Lavrijsen JC, Hoenderdaal PL, de Letter-van der Heide L, Wijnen VJ, Scheirs JG, de Kort PL, Prevo AJ (2009) The reliability and validity of the PALOC-s: a post-acute level of consciousness scale for assessment of young patients with prolonged disturbed consciousness after brain injury. *Neuropsychological rehabilitation* 19:1-27.
- Eldar E, Cohen JD, Niv Y (2013) The effects of neural gain on attention and learning. *Nat Neurosci* 16:1146-1153.
- Endrass T, Franke C, Kathmann N (2005) Error Awareness in a Saccade Countermanding Task. *Journal of Psychophysiology* 19:275-280.
- Eriksen BA, Eriksen CW (1974) Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics* 16:143-149.
- Eschenko O, Magri C, Panzeri S, Sara SJ (2012) Noradrenergic neurons of the locus coeruleus are phase locked to cortical up-down states during sleep. *Cereb Cortex* 22:426-435.
- Esterman M, Noonan SK, Rosenberg M, DeGutis J (2013) In the Zone or Zoning Out? Tracking Behavioral and Neural Fluctuations During Sustained Attention. *Cereb Cortex* 23:2712-2723.
- Estraneo A, Loreto V, Guarino I, Boemia V, Paone G, Moretta P, Trojano L (2016) Standard EEG in diagnostic process of prolonged disorders of consciousness. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology* 127:2379-2385.
- Fellinger R, Klimesch W, Schnakers C, Perrin F, Freunberger R, Gruber W, Laureys S, Schabus M (2011) Cognitive processes in disorders of consciousness as revealed by EEG time-frequency analyses. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology* 122:2177-2184.
- Filippini N, MacIntosh BJ, Hough MG, Goodwin GM, Frisoni GB, Smith SM, Matthews PM, Beckmann CF, Mackay CE (2009) Distinct patterns of brain activity in young carriers of the APOE-epsilon4 allele. *Proc Natl Acad Sci U S A* 106:7209-7214.
- Fischer C, Luaute J, Morlet D (2010) Event-related potentials (MMN and novelty P3) in permanent vegetative or minimally conscious states. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology* 121:1032-1042.
- Fisher N (1993) *Statistical analysis of circular data*. Cambridge, UK Cambridge UP.
- Forstmann BU, Ratcliff R, Wagenmakers EJ (2016) Sequential Sampling Models in Cognitive Neuroscience: Advantages, Applications, and Extensions. *Annual review of psychology* 67:641-666.
- Fox MD, Raichle ME (2007) Spontaneous fluctuations in brain activity observed with functional magnetic resonance imaging. *Nat Rev Neurosci* 8:700-711.
- Fox MD, Snyder AZ, Vincent JL, Corbetta M, Van Essen DC, Raichle ME (2005) The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proc Natl Acad Sci U S A* 102:9673-9678.

- Franklin MS, Broadway JM, Mrazek MD, Smallwood J, Schooler JW (2013) Window to the wandering mind: pupillometry of spontaneous thought while reading. *Quarterly journal of experimental psychology* 66:2289-2294.
- Freeman J, Donner TH, Heeger DJ (2011) Inter-area correlations in the ventral visual pathway reflect feature integration. *Journal of vision* 11.
- Friston KJ, Büchel C (2004) Functional connectivity. In: *Human brain function*, Ed 2 (Frackowiak RJS, ed). San Diego: Academic.
- Gehring WJ, Fencsik DE (2001a) Functions of the medial frontal cortex in the processing of conflict and errors. *The Journal of Neuroscience* 21:9430-3437.
- Gehring WJ, Fencsik DE (2001b) Functions of the medial frontal cortex in the processing of conflict and errors. *Journal of Neuroscience* 21:9430-3437.
- Giacino JT (1997) Disorders of consciousness: differential diagnosis and neuropathologic features. *Seminars in Neurology* 17:105-111.
- Giacino JT, Fins JJ, Laureys S, Schiff ND (2014) Disorders of consciousness after acquired brain injury: the state of the science. *Nature reviews Neurology* 10:99-114.
- Giacino JT, Ashwal S, Childs N, Cranford R, Jennett B, Katz DI, Kelly JP, Rosenberg JH, Whyte J, Zafonte RD, Zasler ND (2002) The minimally conscious state: definition and diagnostic criteria. *Neurology* 58:349-353.
- Gilzenrat MS, Nieuwenhuis S, Jepma M, Cohen JD (2010) Pupil diameter tracks changes in control state predicted by the adaptive gain theory of locus coeruleus function. *Cognitive, affective & behavioral neuroscience* 10:252-269.
- Glover GH, Li T-Q, Ress D (2000) Image-based method for retrospective correction of physiological motion effects in fMRI: RETROICOR. *Magn Reson Med* 44:162-167.
- Grandchamp R, Braboszcz C, Delorme A (2014) Oculometric variations during mind wandering. *Frontiers in psychology* 5:31.
- Greenberg DS, Houweling AR, Kerr JN (2008) Population imaging of ongoing neuronal activity in the visual cortex of awake rats. *Nat Neurosci* 11:749-751.
- Greicius MD, Srivastava G, Reiss AL, Menon V (2004) Default-mode network activity distinguishes Alzheimer's disease from healthy aging: evidence from functional MRI. *Proc Natl Acad Sci USA* 101:4637-4642.
- Griffanti L, Salimi-Khorshidi G, Beckmann CF, Auerbach EJ, Douaud G, Sexton CE, Zsoldos E, Ebmeier KP, Filippini N, Mackay CE, Moeller S, Xu J, Yacoub E, Baselli G, Ugurbil K, Miller KL, Smith SM (2014) ICA-based artefact removal and accelerated fMRI acquisition for improved resting state network imaging. *Neuroimage* 95:232-247.
- Guedj C, Monfardini E, Reynaud AJ, Farne A, Meunier M, Hadj-Bouziane F (2016) Boosting Norepinephrine Transmission Triggers Flexible Reconfiguration of Brain Networks at Rest. *Cereb Cortex*.
- Hajcak G, McDonald N, Simons RF (2003) To err is autonomic: Error-related brain potentials, ANS activity, and post-error compensatory behavior. *Psychophysiol* 40:895-903.
- Harris KD, Thiele A (2011) Cortical state and attention. *Nat Rev Neurosci* 12:509-523.
- Haynes JD, Lotto RB, Rees G (2004) Responses of human visual cortex to uniform surfaces. *Proc Natl Acad Sci USA* 101:4286-4291.
- Haynes JD, Driver J, Rees G (2005) Visibility reflects dynamic changes of effective connectivity between V1 and fusiform cortex. *Neuron* 46:811-821.

- Henry MJ, Obleser J (2012) Frequency modulation entrains slow neural oscillations and optimizes human listening behavior. *Proc Natl Acad Sci U S A* 109:20095-20100.
- Hiltunen T, Kantola J, Abou Elseoud A, Lepola P, Suominen K, Starck T, Nikkinen J, Remes J, Tervonen O, Palva S, Kiviniemi V, Palva JM (2014) Infra-slow EEG fluctuations are correlated with resting-state network dynamics in fMRI. *J Neurosci* 34:356-362.
- Hipp JF, Hawellek DJ, Corbetta M, Siegel M, Engel AK (2012) Large-scale cortical correlation structure of spontaneous oscillatory activity. *Nat Neurosci* 15:884-890.
- Hoeks B, Levitt WJ (1993) Pupillary dilation as a measure of attention: A quantitative system analysis. *Behavior Research Methods, Instruments & Computers* 25:16-26.
- Höller Y, Bergmann J, Kronbichler M, Crone JS, Schmid EV, Golaszewski S, Ladurner G (2011) Preserved oscillatory response but lack of mismatch negativity in patients with disorders of consciousness. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology* 122:1744-1754.
- Hopstaken JF, van der Linden D, Bakker AB, Kompier MA (2015a) The window of my eyes: Task disengagement and mental fatigue covary with pupil dynamics. *Biol Psychol* 110:100-106.
- Hopstaken JF, van der Linden D, Bakker AB, Kompier MA (2015b) A multifaceted investigation of the link between mental fatigue and task disengagement. *Psychophysiol* 52:305-315.
- Hughes G, Yeung N (2011) Dissociable correlates of response conflict and error awareness in error-related brain activity. *Neuropsychologia* 49:405-415.
- Invernizzi RW, Garattini S (2004) Role of presynaptic alpha2-adrenoceptors in antidepressant action: recent findings from microdialysis studies. *Prog Neuropsychopharmacol Biol Psychiatry* 28:819-827.
- Ishimatsu M, Williams JT (1996) Synchronous activity in locus coeruleus results from dendritic interactions in pericoerulear regions. *J Neurosci* 16:5196-5204.
- Jenkinson M, Beckmann CF, Behrens TE, Woolrich MW, Smith SM (2012) Fsl. *Neuroimage* 62:782-790.
- Jennett B, Plum F (1972) Persistent Vegetative State After Brain Damage: A Syndrome in Search of Name. *The Lancet* 1:734-737.
- Jentsch I, Dudschig C (2009) Why do we slow down after an error? Mechanisms underlying the effects of posterror slowing. *Quarterly journal of experimental psychology* 62:209-218.
- Jepma M, Nieuwenhuis S (2011) Pupil Diameter Predicts Changes in the Exploration–Exploitation Trade-off: Evidence for the Adaptive Gain Theory. *Journal of Cognitive Neuroscience* 23:1587-1596.
- Joshi S, Li Y, Kalwani Rishi M, Gold Joshua I (2016) Relationships between Pupil Diameter and Neuronal Activity in the Locus Coeruleus, Colliculi, and Cingulate Cortex. *Neuron* 89:221-234.
- Kahneman D, Beatty J (1966) Pupil diameter and load on memory. *Science* 154:1583-1585.
- Kahneman D, Beatty J (1967) Pupillary responses in a pitch-discrimination task. *Perception and Psychophysics* 2:101-105.
- Kang OE, Huffer KE, Wheatley TP (2014) Pupil dilation dynamics track attention to high-level information. *PLoS One* 9:e102463.

- Kempadoo KA, Mosharov EV, Choi SJ, Sulzer D, Kandel ER (2016) Dopamine release from the locus coeruleus to the dorsal hippocampus promotes spatial learning and memory. *Proc Natl Acad Sci U S A* 113:14835-14840.
- King JA, Korb FM, von Cramon DY, Ullsperger M (2010) Post-error behavioral adjustments are facilitated by activation and suppression of task-relevant and task-irrelevant information processing. *The Journal of Neuroscience* 30:12759-12769.
- King JR, Sitt JD, Faugeras F, Rohaut B, El Karoui I, Cohen L, Naccache L, Dehaene S (2013) Information sharing in the brain indexes consciousness in noncommunicative patients. *Curr Biol* 23:1914-1919.
- Klaassens BL, Rombouts SA, Winkler AM, van Gorsel HC, van der Grond J, van Gerven JM (2017) Time related effects on functional brain connectivity after serotonergic and cholinergic neuromodulation. *Hum Brain Mapp* 38:308-325.
- Klaassens BL, van Gorsel HC, Khalili-Mahani N, van der Grond J, Wyman BT, Whitcher B, Rombouts SA, van Gerven JM (2015) Single-dose serotonergic stimulation shows widespread effects on functional brain connectivity. *Neuroimage* 122:440-450.
- Klumpers LE, Cole DM, Khalili-Mahani N, Soeter RP, Te Beek ET, Rombouts SA, van Gerven JM (2012) Manipulating brain connectivity with delta(9)-tetrahydrocannabinol: a pharmacological resting state fMRI study. *Neuroimage* 63:1701-1711.
- Koda K, Ago Y, Cong Y, Kita Y, Takuma K, Matsuda T (2010) Effects of acute and chronic administration of atomoxetine and methylphenidate on extracellular levels of noradrenaline, dopamine and serotonin in the prefrontal cortex and striatum of mice. *J Neurochem* 114:259-270.
- Kotchoubey B, Lang S, Mezger G, Schmalohr D, Schneck M, Semmler A, Bostanov V, Birbaumer N (2005) Information processing in severe disorders of consciousness: vegetative state and minimally conscious state. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology* 116:2441-2453.
- Kristjansson SD, Stern JA, Brown TB, Rohrbaugh JW (2009) Detecting phasic lapses in alertness using pupillometric measures. *Applied ergonomics* 40:978-986.
- Lakatos P, Schroeder CE, Leitman DI, Javitt DC (2013) Predictive suppression of cortical excitability and its deficit in schizophrenia. *The Journal of Neuroscience* 33:1692-11702.
- Lakatos P, Karmos G, Mehta AD, Ulbert I, Schroeder CE (2008) Entrainment of neuronal oscillations as a mechanism of attentional selection. *Science* 320:110-113.
- Laming D (1979) Choice reaction performance following an error. *Acta Psychologica* 43:199-224.
- Large EW, Jones MR (1999) The dynamics of attending: How people track time-varying events. *Psychological Review* 106:119-159.
- Laureys S, Owen AM, Schiff ND (2004) Brain function in coma, vegetative state, and related disorders. *The Lancet Neurology* 3:537-546.
- Laureys S, Faymonville ME, Luxen A, Lamy M, Franck G, Maquet P (2000) Restoration of thalamocortical connectivity after recovery from persistent vegetative state. *The Lancet* 355:1790-1791.
- Le Martelot E, Hankin C (2013) Multi-scale community detection using stability optimisation. *Int J of Web Based Communities* 9:323-348.

- Lechinger J, Bothe K, Pichler G, Michitsch G, Donis J, Klimesch W, Schabus M (2013) CRS-R score in disorders of consciousness is strongly related to spectral EEG at rest. *Journal of neurology* 260:2348-2356.
- Lehembre R, Bruno M-A, Vanhaudenhuyse A, Chatelle C, Colgan V, Leclercq Y, Soddu A, Marcq B, Laureys S, Noirhomme Q (2012) Resting-state EEG study of comatose patients: a connectivity and frequency analysis to find differences between vegetative and minimally conscious states. *Functional Neurology* 27:41-47.
- Lemieux M, Chen JY, Lonjers P, Bazhenov M, Timofeev I (2014) The impact of cortical deafferentation on the neocortical slow oscillation. *J Neurosci* 34:5689-5703.
- Leopold DA, Murayama Y, Logothetis NK (2003) Very slow activity fluctuations in monkey visual cortex: Implications for functional brain imaging. *Cereb Cortex* 13:422-433.
- Li N, Ma N, Liu Y, He XS, Sun DL, Fu XM, Zhang X, Han S, Zhang DR (2013) Resting-State Functional Connectivity Predicts Impulsivity in Economic Decision-Making. *Journal of Neuroscience* 33:4886-4895.
- Logothetis NK (2008) What we can do and what we cannot do with fMRI. *Nature* 453:869-878.
- Luczak A, Bartho P, Harris KD (2009) Spontaneous events outline the realm of possible sensory responses in neocortical populations. *Neuron* 62:413-425.
- Mackworth NH (1948) The breakdown of vigilance during prolonged visual search. *Quarterly journal of experimental psychology* 1:6-21.
- Mackworth NH (1968) Vigilance, arousal and habituation. *Psychological Review* 75:308-322.
- Maltseva I, Giessler H-G, Başar E (2000) Alpha oscillations as an indicator of dynamic memory operations - anticipation of omitted stimuli. *International Journal of Psychophysiology* 36:185-197.
- Marco-Pallarés J, Camara E, Münte TF, Rodríguez-Fornells A (2008) Neural mechanisms underlying adaptive actions after slips. *Journal of Cognitive Neuroscience* 20:1595-1610.
- Marder E (2012) Neuromodulation of neuronal circuits: back to the future. *Neuron* 76:1-11.
- Marder E, O'Leary T, Shruti S (2014) Neuromodulation of circuits with variable parameters: single neurons and small circuits reveal principles of state-dependent and robust neuromodulation. *Annual review of neuroscience* 37:329-346.
- Maris E, Oostenveld R (2007) Nonparametric statistical testing of EEG- and MEG-data. *The Journal of Neuroscience Methods* 164:177-190.
- Maslov S, Sneppen K (2002) Specificity and stability in topology of protein networks. *Science* 296:910-913.
- Mather M, Clewett D, Sakaki M, Harley CW (2015) Norepinephrine ignites local hot spots of neuronal excitation: How arousal amplifies selectivity in perception and memory. *Behavioral and Brain Sciences*:e200.
- Mathôt S, Siebold A, Donk M, Vitu F (2015) Large Pupils Predict Goal-Driven Eye Movements. *Journal of Experimental Psychology: General* 144:513-521.
- McCabe C, Mishor Z (2011) Antidepressant medications reduce subcortical-cortical resting-state functional connectivity in healthy volunteers. *Neuroimage* 57:1317-1323.
- McGinley Matthew J, David Stephen V, McCormick David A (2015a) Cortical Membrane Potential Signature of Optimal States for Sensory Signal Detection. *Neuron* 87:179-192.

- McGinley MJ, Vinck M, Reimer J, Batista-Brito R, Zagha E, Cadwell CR, Tolias AS, Cardin JA, McCormick DA (2015b) Waking State: Rapid Variations Modulate Neural and Behavioral Responses. *Neuron* 87:1143-1161.
- McLean RA, Sanders WL, Stroup WW (1991) A unified approach to mixed linear models. *The American Statistician* 45:54-64.
- Metzger CD, Wiegers M, Walter M, Abler B, Graf H (2015) Local and global resting state activity in the noradrenergic and dopaminergic pathway modulated by reboxetine and amisulpride in healthy subjects. *Int J Neuropsychopharmacol*:1-9.
- Mitra PP, Pesaran B (1999) Analysis of dynamic brain imaging data. *Biophysical Journal* 76:691-708.
- Mittner M, Boekel W, Tucker AM, Turner BM, Heathcote A, Forstmann BU (2014) When the brain takes a break: a model-based analysis of mind wandering. *J Neurosci* 34:16286-16295.
- Moises HC, Woodward BJ, Hoffer BJ, Freedman R (1979) Interactions of norepinephrine with Purkinje cell responses to putative amino acid neurotransmitters applied by microiontophoresis. *Experimental Neurology* 64:493-515.
- Monti MM, Vanhaudenhuyse A, Coleman MR, Boly M, Pickard JD, Tshibanda L, Owen AM, Laureys S (2010) Willful Modulation of Brain Activity in Disorders of Consciousness. *The New England Journal of Medicine* 362:579-589.
- Mouton PR, Pakkenberg B, Gundersen HJ, Price DL (1994) Absolute number and size of pigmented locus coeruleus neurons in young and aged individuals. *Journal of Chemical Neuroanatomy* 7:185-190.
- Murphy PR, Vandekerckhove J, Nieuwenhuis S (2014a) Pupil-Linked Arousal Determines Variability in Perceptual Decision Making. *PLoS Comput Biol* 10:e1003854.
- Murphy PR, van Moort ML, Nieuwenhuis S (2016) The pupillary orienting response predicts adaptive behavioral adjustment after errors. *PloS One* 11:e0151763.
- Murphy PR, Robertson IH, Balsters JH, O'Connell R G (2011) Pupillometry and P3 index the locus coeruleus-noradrenergic arousal function in humans. *Psychophysiol* 48:1532-1543.
- Murphy PR, Robertson IH, Allen D, Hester R, O'Connell RG (2012) An electrophysiological signal that precisely tracks the emergence of error awareness. *Frontiers in human neuroscience* 6:65.
- Murphy PR, O'Connell RG, O'Sullivan M, Robertson IH, Balsters JH (2014b) Pupil diameter covaries with BOLD activity in human locus coeruleus. *Hum Brain Mapp* 35:4140-4154.
- Nahimi A, Jakobsen S, Munk OL, Vang K, Phan JA, Rodell A, Gjedde A (2015) Mapping alpha2 adrenoceptors of the human brain with 11C-yohimbine. *J Nucl Med* 56:392-398.
- Narayanan NS, Cavanagh JF, Frank MJ, Laubach M (2013) Common medial frontal mechanisms of adaptive control in humans and rodents. *Nat Neurosci* 16:1888-1895.
- Ng BS, Schroeder T, Kayser C (2012) A precluding but not ensuring role of entrained low-frequency oscillations for auditory perception. *The Journal of Neuroscience* 32:12268-12276.
- Nichols TE, Holmes AP (2001) Nonparametric permutation tests for functional neuroimaging: A primer with examples. *Hum Brain Mapp* 15:1-25.

- Nieuwenhuis S, De Geus EJ, Aston-Jones G (2010) The anatomical and functional relationship between the P3 and autonomic components of the orienting response. *Psychophysiol.*
- Nir Y, Hasson U, Levy I, Yeshurun Y, Malach R (2006) Widespread functional connectivity and fMRI fluctuations in human visual cortex in the absence of visual stimulation. *Neuroimage* 30:1313-1324.
- Notebaert W, Houtman F, Opstal FV, Gevers W, Fias W, Verguts T (2009) Post-error slowing: an orienting account. *Cognition* 111:275-279.
- Nunez Castellar E, Kuhn S, Fias W, Notebaert W (2010) Outcome expectancy and not accuracy determines posterror slowing: ERP support. *Cognitive, affective & behavioral neuroscience* 10:270-278.
- Nunez MD, Srinivasan R, Vandekerckhove J (2015) Individual differences in attention influence perceptual decision making. *Frontiers in psychology* 8:18.
- Okun M, Lampl I (2008) Instantaneous correlation of excitation and inhibition during ongoing and sensory-evoked activities. *Nat Neurosci* 11:535-537.
- Owen AM, Coleman MR, Boly M, Davis MH, Laureys S, Pickard JD (2006) Detecting awareness in the vegetative state. *Science* 313:1402.
- Pace-Schott EF, Hobson JA (2002) The neurobiology of sleep: genetics, cellular physiology and subcortical networks. *Nat Rev Neurosci* 3:591-605.
- Piarulli A, Bergamasco M, Thibaut A, Cologan V, Gosseries O, Laureys S (2016) EEG ultradian rhythmicity differences in disorders of consciousness during wakefulness. *Journal of neurology* 263:1746-1760.
- Poulet JF, Petersen CC (2008) Internal brain state regulates membrane potential synchrony in barrel cortex of behaving mice. *Nature* 454:881-885.
- Power JD, Plitt M, Laumann TO, Martin A (2017) Sources and implications of whole-brain fMRI signals in humans. *Neuroimage* 146:609-625.
- Rabbitt P (1966) Errors and error correction in choice-response tasks. *Journal of Experimental Psychology* 71:264-272.
- Reimer J, Froudarakis E, Cadwell CR, Yatsenko D, Denfield GH, Tolias AS (2014) Pupil fluctuations track fast switching of cortical states during quiet wakefulness. *Neuron* 84:355-362.
- Reimer J, McGinley MJ, Liu Y, Rodenkirch C, Wang Q, McCormick DA, Tolias AS (2016) Pupil fluctuations track rapid changes in adrenergic and cholinergic activity in cortex. *Nature communications* 7:13289.
- Ridderinkhof KR (2002) Micro- and macro-adjustments of task set: activation and suppression in conflict tasks. *Psychological research* 66:312-323.
- Robertson IH, Manly T, Andrade J, Braddeley BT, Yiend J (1997) 'Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia* 35:747-758.
- Robinson ES, Eagle DM, Mar AC, Bari A, Banerjee G, Jiang X, Dalley JW, Robbins TW (2008) Similar effects of the selective noradrenaline reuptake inhibitor atomoxetine on three distinct forms of impulsivity in the rat. *Neuropsychopharmacol* 33:1028-1037.
- Rodgers EW, Krenz WD, Baro DJ (2011a) Tonic dopamine induces persistent changes in the transient potassium current through translational regulation. *J Neurosci* 31:13046-13056.
- Rodgers EW, Fu JJ, Krenz WD, Baro DJ (2011b) Tonic nanomolar dopamine enables an activity-dependent phase recovery mechanism that persistently alters the maximal conductance of the hyperpolarization-activated current in a rhythmically active neuron. *J Neurosci* 31:16387-16397.

- Rogawski MA, Aghajanian GK (1980) Modulation of lateral geniculate neurone excitability by noradrenaline microiontophoresis or locus coeruleus stimulation. *Nature* 287:731-734.
- Rombouts SA, Barkhof F, Goekoop R, Stam CJ, Scheltens P (2005) Altered resting state networks in mild cognitive impairment and mild Alzheimer's disease: an fMRI study. *Hum Brain Mapp* 26:231-239.
- Rosanova M, Gosseries O, Casarotto S, Boly M, Casali AG, Bruno MA, Mariotti M, Boveroux P, Tononi G, Laureys S, Massimini M (2012) Recovery of cortical effective connectivity and recovery of consciousness in vegetative patients. *Brain : a journal of neurology* 135:1308-1320.
- Rubinov M, Sporns O (2010) Complex network measures of brain connectivity: Uses and interpretations. *Neuroimage* 52:1059-1069.
- Safaai H, Neves R, Eschenko O, Logothetis NK, Panzeri S (2015) Modeling the effect of locus coeruleus firing on cortical state dynamics and single-trial sensory processing. *Proc Natl Acad Sci U S A* 112:12834-12839.
- Saleh M, Reimer J, Penn R, Ojakangas CL, Hatsopoulos NG (2010) Fast and slow oscillations in human primary motor cortex predict oncoming behaviorally relevant cues. *Neuron* 65:461-471.
- Salimi-Khorshidi G, Douaud G, Beckmann CF, Glasser MF, Griffanti L, Smith SM (2014) Automatic denoising of functional MRI data: combining independent component analysis and hierarchical fusion of classifiers. *Neuroimage* 90:449-468.
- Sara SJ, Bouret S (2012) Orienting and reorienting: the locus coeruleus mediates cognition through arousal. *Neuron* 76:130-141.
- Schiff ND (2010) Recovery of consciousness after brain injury: a mesocircuit hypothesis. *Trends in neurosciences* 33:1-9.
- Schiff ND, Nauvel T, Victor JD (2014) Large-scale brain dynamics in disorders of consciousness. *Current opinion in neurobiology* 25:7-14.
- Schiff ND, Giacino JT, Kalmar K, Victor JD, Baker K, Gerber M, Fritz B, Eisenberg B, Biondi T, O'Connor J, Kobylarz EJ, Farris S, Machado A, McCagg C, Plum F, Fins JJ, Rezai AR (2007) Behavioural improvements with thalamic stimulation after severe traumatic brain injury. *Nature* 448:600-603.
- Schölvinck ML, Maier A, Ye FQ, Duyn JH, Leopold DA (2010) Neural basis of global resting-state fMRI activity. *Proc Natl Acad Sci USA* 107:10238-10243.
- Schorr B, Schlee W, Arndt M, Bender A (2016) Coherence in resting-state EEG as a predictor for the recovery from unresponsive wakefulness syndrome. *Journal of neurology* 263:937-953.
- Schranz A, Ferguson B, Stoffers D, Booij J, Rombouts S, Reneman L (2016) Effects of dexamphetamine-induced dopamine release on resting-state network connectivity in recreational amphetamine users and healthy controls. *Brain imaging and behavior* 10:548-558.
- Schroeder CE, Lakatos P (2009) Low-frequency neuronal oscillations as instruments of sensory selection. *Trends in neurosciences* 32:9-18.
- Schurger A, Sarigiannidis I, Naccache L, Sitt JD, Dehaene S (2015) Cortical activity is more stable when sensory stimuli are consciously perceived. *Proc Natl Acad Sci U S A* 112:E2083-2092.
- Schwarz G (1978) Estimating dimension of a model. *Ann Stat* 6:461-464.
- Schwarz LA, Luo L (2015) Organization of the Locus Coeruleus-Norepinephrine System. *Curr Biol* 25:R1051-1056.

- Schwarz LA, Miyamichi K, Gao XJ, Beier KT, Weissbourd B, DeLoach KE, Ren J, Ibanes S, Malenka RC, Kremer EJ, Luo L (2015) Viral-genetic tracing of the input-output organization of a central noradrenaline circuit. *Nature* 524:88-92.
- Seamans JK, Gorelova N, Durstewitz D, Yang CR (2001a) Bidirectional dopamine modulation of GABAergic inhibition in prefrontal cortical pyramidal neurons. *J Neurosci* 21:3628–3638.
- Seamans JK, Durstewitz D, Christie BR, Stevens CF, Sejnowski TJ (2001b) Dopamine D1/D5 receptor modulation of excitatory synaptic inputs to layer V prefrontal cortex neurons. *Proc Natl Acad Sci U S A* 98:301-306.
- Seeley WW, Menon V, Schatzberg AF, Keller J, Glover GH, Kenna H, Reiss AL, Greicius MD (2007) Dissociable intrinsic connectivity networks for salience processing and executive control. *J Neurosci* 27:2349-2356.
- Sepulcre J, Liu H, Talukdar T, Martincorena I, Yeo BT, Buckner RL (2010) The organization of local and distant functional connectivity in the human brain. *PLoS Comput Biol* 6:e1000808.
- Servan-Schreiber D, Printz H, Cohen JD (1990) A network model of catecholamine effects: gain, signal-to-noise ratio, and behavior. *Science* 249:892-895.
- Shine JM, Bissett PG, Bell PT, Koyejo O, Balsters JH, Gorgolewski KJ, Moodie CA, Poldrack RA (2016) The Dynamics of Functional Brain Networks: Integrated Network States during Cognitive Task Performance. *Neuron* 92:544-554.
- Siegel M, Donner TH, Engel AK (2012) Spectral fingerprints of large-scale neuronal interactions. *Nat Rev Neurosci* 13:121-134.
- Siems M, Pape AA, Hipp JF, Siegel M (2016) Measuring the cortical correlation structure of spontaneous oscillatory activity with EEG and MEG. *Neuroimage* 129:345-355.
- Sitt JD, King JR, El Karoui I, Rohaut B, Faugeras F, Gramfort A, Cohen L, Sigman M, Dehaene S, Naccache L (2014) Large scale screening of neural signatures of consciousness in patients in a vegetative or minimally conscious state. *Brain : a journal of neurology* 137:2258-2270.
- Smallwood J, Brown KS, Baird B, Mrazek MD, Franklin MS, Schooler JW (2012) Insulation for daydreams: a role for tonic norepinephrine in the facilitation of internally guided thought. *PLoS One* 7:e33706.
- Smallwood J, Brown KS, Tipper C, Giesbrecht B, Franklin MS, Mrazek MD, Carlson JM, Schooler JW (2011) Pupillometric evidence for the decoupling of attention from perceptual input during offline thought. *PLoS One* 6:e18298.
- Smith SM, Fox PT, Miller KL, Glahn DC, Fox PM, Mackay CE, Filippini N, Watkins KE, Toro R, Laird AR, Beckmann CF (2009) Correspondence of the brain's functional architecture during activation and rest. *Proc Natl Acad Sci U S A* 106:13040-13045.
- Smith SM, Jenkinson M, Woolrich MW, Beckmann CF, Behrens TE, Johansen-Berg H, Bannister PR, De Luca M, Drobnjak I, Flitney DE, Niazy RK, Saunders J, Vickers J, Zhang Y, De Stefano N, Brady JM, Matthews PM (2004) Advances in functional and structural MR image analysis and implementation as FSL. *Neuroimage* 23 Suppl 1:S208-219.
- Stefanics G, Hangya B, Hernadi I, Winkler I, Lakatos P, Ulbert I (2010a) Phase entrainment of human delta oscillations can mediate the effects of expectation on reaction speed. *The Journal of Neuroscience* 30:13578-13585.
- Stefanics G, Hangya B, Hernadi I, Winkler I, Lakatos P, Ulbert I (2010b) Phase entrainment of human delta oscillations can mediate the effects of expectation on reaction speed. *Journal of neuroscience* 30:13578-13585.

- Steinborn MB, Flehmig HC, Bratzke D, Schroter H (2012) Error reactivity in self-paced performance: Highly-accurate individuals exhibit largest post-error slowing. *Quarterly journal of experimental psychology* 65:624-631.
- Steinhauser M, Yeung N (2012) Error awareness as evidence accumulation: effects of speed-accuracy trade-off on error signaling. *Frontiers in human neuroscience* 6:240.
- Stender J, Mortensen KN, Thibaut A, Darkner S, Laureys S, Gjedde A, Kupers R (2016) The Minimal Energetic Requirement of Sustained Awareness after Brain Injury. *Curr Biol* 26:1494-1499.
- Sulzer D, Cragg SJ, Rice ME (2016) Striatal dopamine neurotransmission: regulation of release and uptake. *Basal ganglia* 6:123-148.
- Swanson CJ, Perry KW, Koch-Krueger S, Katner J, Svensson KA, Bymaster FP (2006) Effect of the attention deficit/hyperactivity disorder drug atomoxetine on extracellular concentrations of norepinephrine and dopamine in several brain regions of the rat. *Neuropharmacology* 50:755-760.
- Swanson LW, Hartman BK (1975) The central adrenergic system. An immunofluorescence study of the location of cell bodies and their efferent connections in the rat utilizing dopamine-beta-hydroxylase as a marker. *J Comp Neurol* 163:467-505.
- Takeuchi T, Duzkiewicz AJ, Sonneborn A, Spooner PA, Yamasaki M, Watanabe M, Smith CC, Fernandez G, Deisseroth K, Greene RW, Morris RG (2016) Locus coeruleus and dopaminergic consolidation of everyday memory. *Nature* 537:357-362.
- Tallon-Baudry C, Bertrand O (1999) Oscillatory gamma activity in humans and its role in object representation. *Trends in cognitive sciences* 3:151-162.
- Tavor I, Parker Jones O, Mars RB, Smith SM, Behrens TE, Jbabdi S (2016) Task-free MRI predicts individual differences in brain activity during task performance. *Science* 352:216-220.
- Thiebaut de Schotten M, Dell'Acqua F, Forkel SJ, Simmons A, Vergani F, Murphy DG, Catani M (2011) A lateralized brain network for visuospatial attention. *Nat Neurosci* 14:1245-1246.
- Timofeev I, Grenier F, Bazhenov M, Sejnowski TJ, Steriade M (2000) Origin of slow cortical oscillations in deafferented cortical slabs. *Cereb Cortex* 10:1185-1199.
- Totah NK, Neves RM, Panzeri S, Logothetis NK, Eschenko O (2017) Monitoring large populations of locus coeruleus neurons reveals the non-global nature of the norepinephrine neuromodulatory system. *bioRxiv*.
- Tzourio-Mazoyer N, Landeau B, Papathanassiou D, Crivello F, Etard O, Delcroix N, Mazoyer B, Joliot M (2002) Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *Neuroimage* 15:273-289.
- Ullsperger M, Harsay HA, Wessel JR, Ridderinkhof KR (2010) Conscious perception of errors and its relation to the anterior insula. *Brain structure & function* 214:629-643.
- Unsworth N, Robison MK (2016) Pupillary correlates of lapses of sustained attention. *Cognitive, affective & behavioral neuroscience*.
- van den Brink RL, Wynn SC, Nieuwenhuis S (2014) Post-error slowing as a consequence of disturbed low-frequency oscillatory phase entrainment. *J Neurosci* 34:11096-11105.
- van den Brink RL, Pfeffer T, Warren CM, Murphy PR, Tona KD, van der Wee NJ, Giltay E, van Noorden MS, Rombouts SA, Donner TH, Nieuwenhuis S (2016)

- Catecholaminergic Neuromodulation Shapes Intrinsic MRI Functional Connectivity in the Human Brain. *J Neurosci* 36:7865-7876.
- Van Dijk KR, Sabuncu MR, Buckner RL (2012) The influence of head motion on intrinsic functional connectivity MRI. *Neuroimage* 59:431-438.
- Van Orden KF, Jung T-P, Makeig S (2000) Combined eye activity measures accurately estimate changes in sustained visual task performance. *Biological Psychology* 52:221-240.
- van Wijk BCM, Stam CJ, Daffershofer A (2010) Comparing brain networks of different size and connectivity density using graph theory. *PLoS One* 5:e13701.
- Varazzani C, San-Galli A, Gilardeau S, Boret S (2015) Noradrenaline and dopamine neurons in the reward/effort trade-off: a direct electrophysiological comparison in behaving monkeys. *J Neurosci* 35:7866-7877.
- Varotto G, Fazio P, Rossi Sebastiano D, Duran D, D'Incerti L, Parati E, Sattin D, Leonardi M, Franceschetti S, Panzica F (2014) Altered resting state effective connectivity in long-standing vegetative state patients: an EEG study. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology* 125:63-68.
- Wang J, O'Donnell P (2001) D1 dopamine receptors potentiate NMDA-mediated excitability increase in layer V prefrontal cortical pyramidal neurons. *Cereb Cortex* 11.
- Wang X-J (2010) Neurophysiological and computational principles of cortical rhythms in cognition. *Physiological Reviews* 90:1195-1268.
- Warren CM, van den Brink RL, Nieuwenhuis S, Bosch JA (2017) Norepinephrine transporter blocker atomoxetine increases salivary alpha amylase. *Psychoneuroendocrinology* 78:233-236.
- Warren CM, van den Brink RL, Nieuwenhuis S, Bosch JA (in preparation) Testing the controversial claim that salivary alpha amylase is a biomarker of central noradrenergic activity.
- Warren CM, Eldar E, van den Brink RL, Tona KD, van der Wee NJ, Giltay EJ, van Noorden MS, Bosch JA, Wilson RC, Cohen JD, Nieuwenhuis S (2016) Catecholamine-Mediated Increases in Gain Enhance the Precision of Cortical Representations. *J Neurosci* 36:5699-5708.
- Waterhouse BD, Moises HC, Woodward BJ (1998) Phasic activation of the locus coeruleus enhances responses of primary sensory cortical neurons to peripheral receptive field stimulation. *Brain Research* 790:33-44.
- Watts DJ, Strogatz SH (1998) Collective dynamics of 'small-world' networks. *Nature* 393:440-442.
- Weissman DH, Roberts KC, Visscher KM, Woldorff MG (2006) The neural bases of momentary lapses in attention. *Nat Neurosci* 9:971-978.
- White CN, Ratcliff R, Vasey MW, McKoon G (2010) Using diffusion models to understand clinical disorders. *J Math Psychol* 54:39-52.
- Wijnen VJ, van Boxtel GJ, Eilander HJ, de Gelder B (2007) Mismatch negativity predicts recovery from the vegetative state. *Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology* 118:597-605.
- Winterer G, Weinberger DR (2004) Genes, dopamine and cortical signal-to-noise ratio in schizophrenia. *Trends in neurosciences* 27:683-690.
- Wyart V, de Gardelle V, Scholl J, Summerfield C (2012) Rhythmic fluctuations in evidence accumulation during decision making in the human brain. *Neuron* 76:847-858.

- Yeo BT, Krienen FM, Sepulcre J, Sabuncu MR, Lashkari D, Hollinshead M, Roffman JL, Smoller JW, Zollei L, Polimeni JR, Fischl B, Liu H, Buckner RL (2011) The organization of the human cerebral cortex estimated by intrinsic functional connectivity. *J Neurophysiol* 106:1125-1165.
- Yerkes RM, Dodson JD (1908) The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology* 18:459-482.
- Yu AJ, Dayan P (2005) Uncertainty, neuromodulation, and attention. *Neuron* 46:681-692.
- Yuval-Greenberg S, Tomer O, Keren AS, Nelken I, Deouell LY (2008) Transient induced gamma-band response in EEG as a manifestation of miniature saccades. *Neuron* 58:429-441.
- Zagha E, Casale AE, Sachdev RN, McGinley MJ, McCormick DA (2013) Motor cortex feedback influences sensory processing by modulating network state. *Neuron* 79:567-578.
- Zalesky A, Fornito A, Cocchi L, Gollo LL, Breakspear M (2014) Time-resolved resting-state brain networks. *Proc Natl Acad Sci USA* 111:10341-10346.
- Zar JH (1999) *Biostatistical Analysis*, 5th Edition: Prentice Hall.
- Zilles K, Amunts K (2009) Receptor mapping: architecture of the human cerebral cortex. *Current opinion in neurology* 22:331-339.

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Curriculum Vitae

Ruud van den Brink was born in Delft, on the 22nd of September 1987. In 2007, he completed secondary school at the Dominicus College, Nijmegen. He obtained a Bachelor of Science, from the University of Amsterdam in 2010, where he studied Psychobiology. In 2012 he graduated with distinction (*cum laude*) from the research master's program Brain and Cognitive Sciences, also at the University of Amsterdam, earning the degree of Master of Science. In October 2012, he started to work as a PhD student at Leiden University, under the supervision of professor Sander Nieuwenhuis. The work focused on noradrenergic mechanisms for the control of brain state and cognition, and resulted in this thesis. Over the course of the PhD project, Ruud was involved in various extracurricular activities, such as an editorship at the quarterly journal of the Dutch psychonomics society, *de Psychonoom*. In the summer of 2017, he will start working as a postdoc in the lab of professor Tobias Donner, funded by an Alexander von Humboldt fellowship for postdoctoral researchers. The project is targeted at uncovering fast-acting neural mechanisms that facilitate transitions between cognitive states