Discovering Basic Stages in a Visual Discrimination Task

Hermine S. Berberyant, Hedderik van Rijn2, & Jelmer P. Borst1
1 Bernoulli Institute, University of Groningen, Groningen, the Netherlands
2 Department of Experimental Psychology, University of Groningen, Groningen, the Netherlands

Dating back to the 19th century, the discovery of cognitive processing stages has been of great interest among researchers. Major methods which have been used to derive properties of different stages were RT-based methods (Donders, 1868; Sternberg, 1969). Despite their widespread use, these methods were limited in providing direct measures of the ongoing process. Here we used a combination of hidden semi-Markov model analysis (HSMM) and multivariate pattern analysis (MVPA) to analyze EEG data (Anderson, Zhang, Borst, & Walsh, 2016). In contrast to RT-based methods, this method allows to parse a cognitive task into a series of stages based on the many EEG samples within a trial, unlike one RT measure per trial. In the current project, we aimed to discover and catalogue stages of perceptual processing and simple decision making. We designed two experiments where participants had to discriminate between different objects. In both experiments, the same stimuli were presented to participants, however, in Experiment 2 the decisions were more difficult. The resulting HSMM models for both experiments showed a clear difference in duration of one of the stages: a longer stage was observed in Experiment 2 as opposed to Experiment 1. This suggests that this stage represents a slower decision-making process, which was confirmed by additional analyses. We thus conclude that HSMM-MVPA analysis is a versatile method for decomposing various tasks into stages.
Word contexts enhance the neural representation of individual letters in early visual cortex

Micha Heilbron1,2, David Richter1, Matthias Ekman1, Peter Hagoort1,2 & Floris P. de Lange1

1. Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, The Netherlands

Visual context facilitates perception, but how this is neurally implemented remains largely unclear. One famous example of contextual facilitation is found in reading, where letters are more easily identified when embedded in a word. Bottom-up models explain this contextual word advantage as a post-perceptual decision bias, while top-down models propose that word contexts enhance letter perception itself. Here, we examined whether word contexts improve the neural representation of letters by presenting participants streams of words or nonwords and probing the fidelity of letter representations in early visual cortex using functional magnetic resonance imaging (fMRI). In line with top-down neural network simulations, we found that letter representations in visual cortex were enhanced when embedded in word compared to nonword contexts. Moreover, we observed increased information-activation coupling between letter information in early visual cortex and BOLD activity in key areas of the reading network, suggesting these may have been the source of the top-down enhancement. Our results provide the first neural evidence for top-down representational enhancement in word recognition, demonstrating that word contexts can modulate perceptual processing already at the earliest visual cortical regions.
Many experimental studies make use of visual stimuli, especially everyday objects, to investigate various aspects of human cognition. There are several databases that classify these stimuli according to the name agreement, visual complexity, familiarity (Adlington et al., 2008; Brodeur et al., 2010; Horst & Hout, 2015). To the best of our knowledge no databases so far has focused on the novelty of an object based on the individuals’ age and the objects’ frequency of use. Here we discuss the results of the “Italian Known and Unknown Everyday Objects Database” that contains thirty object images (Rio et al., in prep.). 215 participants of four different ranges of age (3-5/6-10/11-17/18-40 years old) were asked to fill an online questionnaire and to answer five written questions about familiarity, naming, function, use and frequency of use of thirty objects classified as high, medium and low in familiarity. The analysis of the responses as regards the familiarity and the frequency of use confirms the initial objects’ classification. In addition, results showed that children were more creative than adults in finding novel objects names and functions. In order to understand how contextual variables influence the naming or other linguistic tasks, our further purpose is to extend the collection of norms of the Italian database to the Dutch and Croatian populations. In conclusion, these results and further ones could provide useful information for researchers who intend to conduct experiments in psychology. They can namely provide information on the use of familiar and non-familiar objects considering the age of individuals and different cultural and linguistic contexts.
Obeying orders reduces vicarious brain activation towards victims’ pain

Kalliopi Ioumpa*, Emilie Caspar*, Christian Keysers, & Valeria Gazzola
Netherlands Institute for Neuroscience, KNAW, Amsterdam, Netherlands

Past historical events and experimental research have shown that complying with the orders of an authority has a strong impact on people’s behaviour. However, the mechanisms underlying how obeying orders influences moral behaviours remain largely unknown. Here, we tested the hypothesis that when people inflict a painful stimulation to another individual, their empathic response is reduced when this action complied with the order of an experimenter (coercive condition) in comparison with being free to decide to inflict that pain (free-choice condition). We observed that even if participants knew that the shock intensity delivered to the ‘victim’ was exactly the same during coercive and free-choice conditions, they rated the shocks as less painful in the coercive condition. fMRI results, from forty participants, further indicated that obeying orders reduced activity associated with witnessing the shocks to the victim in the ACC, insula/IFG, amygdala, TPJ, caudate and the putamen in comparison with being free to decide. These brain regions have been associated with vicarious activations when individuals witness the pain of someone else. Participants felt less responsible in the coercive than in the free-choice condition, which may explain the reduction of neural response associated with empathy. These results highlight that obeying orders has a measurable influence on how people perceive and process others’ pain and may explain people’s willingness to perform moral transgressions in coercive situations.
Predicting others’ action is essential for interacting in the social world (Sebanz & Knoblich, 2009). Action prediction is also linked to motor expertise (Stapel et al., 2016). With motor experience, children’s movement variability during action execution decreases, which indicates a more stable motor representation (Chen et al., 2010). We hypothesised that infants who display more stable movements (low movement variability) are also more stable (less variable) in their predictions of others’ actions. Furthermore, we expected that infants who perform more mature and adult-like actions are more accurate in their temporal predictions of adults’ actions. To examine these links, we tested 58 20-month-old infants (34 girls). Firstly, infants were presented with a set of videos of an adult actor carrying out a placement action, while their eye gaze was measured. The actor grasped a toy, transferred it to the other side of the screen and placed it on a higher container off the screen. Part of the screen was always occluded by a black rectangle, so that the actor’s movements were hidden from view during a part of the stimuli presentation. Infants’ predictive eye movements for the reemergence of the hand behind the occlusion were measured. Then, the infants’ execution skills of the same action were tested, and recorded with a motion capture system. Their task was to transfer a ball from a lower container to a higher one. Moderate evidence was found for a lack of a relationship between the specific components of infants’ action execution and action prediction.
SSVEP phase synchronies and propagation during repetitive visual stimulation at high frequencies

Tsvetomira Tsoneva, Gary Garcia, Peter Desain

Steady-state visual evoked potentials (SSVEPs), the brain response to repetitive visual flicker stimulation, have proven beneficial in both research and clinical applications. Despite the practical advantages of SSVEP responses to stimulation at high frequencies, these have not yet received enough attention and little is known about the mechanisms behind their generation and propagation in time and space. In this study, we investigated the origin and propagation of SSVEPs in the gamma frequency band ($40-60$ Hz) by studying the dynamic properties of EEG in 32 subjects. Using low-resolution brain electromagnetic tomography (LORETA), we estimated the cortical generators of the surface EEG signal related to the fundamental frequency component for all stimulation conditions. We examined the stimulus-evoked changes in the SSVEP phase topography and calculated the phase synchrony between RVS and cortical sources. The results of our study support the theory of dynamic, distributed source configurations underlying the SSVEP generation, organized at large-spatial scales with their spatial properties being sensitive to input frequency.
Bigger volume, less interneurons: are you aggressive? The role of anterior- and midcingulate cortex in aggression and social withdrawal in BALB/cJ mice

S. van Heukelum¹, F. Mogavero¹, M. van de Wal¹, L. Drost¹, V. Bos¹, M. N. Havenith¹*, J. C. Glennon¹*
¹Radboud University Medical Centre, Cognitive Neuroscience / Donders Institute, Nijmegen, The Netherlands
*contributed equally

Successfully navigating social interactions requires the balanced integration of emotional and cognitive cues. One of the main hubs for this integration is cingulate cortex, specifically anterior cingulate cortex (ACC) and midcingulate cortex (MCC). Here, we demonstrate that the volume of ACC/MCC and interneuron populations within ACC/MCC predict aggression and sociability in mice. First, volumes of ACC and MCC were determined in the BALB/cJ mouse, a model demonstrating increased aggression and social deficits. BALB/cJ mice were tested in the resident-intruder-paradigm, demonstrating increased aggression compared to BALB/cByJ mice, a non-aggressive control group. Anatomically, BALB/cJ mice demonstrated an increased volume of ACC but decreased volume of MCC and a high percentage of the variance in aggression was explained by these differences. We then examined interneuron populations (parvalbumin [PV] and somatostatin [SOM]) in BALB/cJ mice phenotyped for their social behaviour (3-chamber task) and aggression. The 3-chamber task revealed two subgroups of highly-sociable versus less-sociable BALB/cJ mice. Highly-sociable BALB/cJ mice were as aggressive as the less-sociable group – in fact, they committed more acts of socially acceptable aggression (harmless bites). PV and SOM immunostaining revealed that a lack of specificity in the distribution of interneurons across cingulate cortex coincided with sociability: Both control mice and highly-sociable BALB/cJ mice showed a differential distribution of PV and SOM interneurons across cingulate cortex, while for less-sociable BALB/cJ mice, the distributions were near-flat. In contrast, both highly-sociable and less-sociable BALB/cJ mice had a decreased concentration of PV interneurons in MCC compared to controls, which was therefore linked to aggressive behavior. Together, these results suggest that the anatomical features of ACC and MCC shape both social and aggressive behavior.
Anticipating object trajectories in the presence of a goal

Andrea Frielink-Loing, Arno Koning, Rob van Lier

We investigated whether attention allocation during Multiple Object Tracking (MOT) is influenced by the presence of a goal. We used adaptations of the MOT paradigm to determine the allocation of attention near tracked objects as they moved towards a goal. In Experiment 1, participants tried to ‘catch’ targets by controlling a goal. A vertical line centred on the screen acted as a wall off which objects bounced. Target bounces triggered the appearance of a probe in either the bounce direction (i.e., real future object location) or linear direction. Participants detected probes better when the target subsequently reached the goal as compared to an empty wall. In Experiment 2, participants additionally controlled the permeability of the vertical wall, allowing objects to move through or bounce off. Again, probes appeared when targets reached the vertical wall. Two corners of the screen were designated fixed goals, one ‘good’ and one ‘bad’. When a target moved towards a ‘good’ goal, probes were detected better when they were congruent compared to incongruent with actual object movement. The opposite was true for targets moving towards a ‘bad’ goal. We conclude that the presence and valence of a goal influences how attention is allocated during object tracking.
Expectations can facilitate the processing of predictable input, but it is less clear whether they have downstream consequences, in particular when the input violates those expectations. In the present EEG study, we presented expectation violations in sentences, followed by a surprise memory test that allowed us to look at the consequences of expectation violations for memory and to link these back to electrophysiological signatures of sentence comprehension. Participants were presented with unexpected but plausible words that violated a likely expectation (“Be careful, the stove is very dirty”, where “hot” was expected) or following a context that did not afford a strong expectation (“He is surprised, because the second object is very dirty”). Constraint affected sentence reading: relative to the weakly constraining condition, expectation violations were characterized by a larger late parietal positivity, as well as beta power decreases prior to and following the violation. Behaviourally, we found better recognition memory for expectation violations than weak constraint controls, suggesting that violations promote memory for the input. In addition, we found downstream effects of expectation violations both on the N400 and the late positive complex during the memory test. Finally, back-sorting items based on subsequent memory responses showed that the late parietal positivity observed during reading was larger in subsequently remembered than subsequently forgotten items, suggesting it might index processes underlying the beneficial effects of expectation violations on memory. Overall, these results show that, although expectation violations are likely costly during on-line processing, they can ultimately be beneficial for memory of the input.
Characterizing neuro-anatomic heterogeneity in people with and without ADHD based on sub-cortical brain volume

Ting Li MD1*, Daan van Rooij PhD2*, Nina Roth Mota PhD1,3, Jan K. Buitelaar MD,PhD2, ENIGMA ADHD Working Group, Martine Hoogman PhD1, Alejandro Arias Vasquez PhD1,2,3, Barbara Franke PhD1,3

1Department of Human Genetics, Donders Institute for Brain, Cognition and Behaviour, Radboud University Medical Center, Nijmegen, The Netherlands
2Department of Cognitive Neuroscience, Donders Institute for Brain, Cognition and Behaviour, Radboud University Medical Center, Nijmegen, The Netherlands
3Department of Psychiatry, Donders Institute for Brain, Cognition and Behaviour, Radboud University Medical Center, Nijmegen, The Netherlands

*equal contribution

Background: Attention-deficit/hyperactivity disorder (ADHD) is a frequent neurodevelopmental disorder in children, which often persists into adulthood. Neuro-anatomic heterogeneity may limit our understanding of the etiology of ADHD.

Objective: To parse neuro-anatomic heterogeneity of ADHD using the largest dataset from the international ENIGMA-ADHD Working Group, and determine whether subgroups could be discerned in patients based on subcortical volumes.

Method: Exploratory factor analysis (EFA) was firstly applied on subcortical brain volume from 563 boys with ADHD and 430 boys without ADHD (age 4-14 years), and subsequently on samples of girls and adults (age >22 years) to uncover the underlying subcortical organization. The factor scores derived from EFA were used to build networks across participants. A community detection (CD) algorithm was used to cluster these networks into subgroups.

Results: Three factors (basal ganglia, limbic system, and thalamus) were found in boys and men. The factor structures in girls and women were different from those observed in males. For boys and men with and without ADHD, groups were separated into four communities. Community 1 was characterized by larger than average volumes in basal ganglia and smaller thalamus; Community 2 was defined by smaller than average volumes in basal ganglia and larger thalamus. Community 3 had larger limbic system, and smaller basal ganglia and thalamus, with Community 4 showing the reverse pattern. Significantly different subcortical volumes in each community between boys with and without ADHD; While no significant differences in ADHD symptom severity between communities, men with ADHD in Community 1 and Community 4 presented more frequent comorbidities than controls.

Conclusion: Our results indicate that neuro-anatomic heterogeneity in subcortical brain volumes exists, with individuals with and without ADHD showing similar patterns. Effect sizes of case-control differences appear more pronounced in some of the four observed subgroups, at least in males.
Decision making in social contexts is extremely important for human beings. Cognitive neuroscience has tried to understand how this behavior comes about, but has been unsuccessful in developing comprehensive computational models of the underlying neural processes. This is mostly due to the difficulty in isolating the constituent computations. Here, we attempt to resolve this issue by taking the opposite strategy: we take a computationally well understood paradigm—evidence accumulation—and convert this to a social situation. Participants underwent fMRI scanning while accumulating evidence about the state of the world and about the perceived state of the world of a confederate. This allowed us to demonstrate that ventro-medial prefrontal and mid-cingulate cortex code decision evidence independent of context, but that dorsal medial frontal areas, including pre-SMA, adjust their activation based on the context of the decision. These results demonstrate the feasibility of using a known computational paradigm to study social decision making.
Expectations in the ventral visual stream result in a gain modulation of neural responses.

David Richter, Micha Heilbron, Floris P. de Lange

Experience is a valuable tool in guiding perception. Indeed, expectations, formed based on previous experiences, have been shown to influence sensory processing throughout the ventral visual stream. In particular, fMRI studies have shown that sensory responses to expected compared to unexpected stimuli are suppressed, while stimulus representations are dampened. However, based on fMRI voxel data, which integrate over millions of neurons, it is difficult to infer how the response properties of neurons are modulated. In fact, several types of response modulation, such as different gain modulations or a sharpening of neural responses, can account for individual fMRI results, if considered in isolation. By combining forward models, mapping individual neural modulations to voxel level data, and a diverse set of fMRI analyses, we show that a gain modulation of neural responses best explains expectation effects in the ventral visual stream. Thereby, our results constrain neuro-computational theories of perception that frame perception as an inferential process, by showing that expectations modulate the gain of visually responsive neurons.
Brain and behavioural changes in mice colonized with human ADHD gut microbiota

Sarita Dam1, Anouk Tengeler2, Maximilian Wiesmann2, Clara Belzer3, Barbara Franke4,5, Tamas Kozicz2, Amanda Kiliaan2, Alejandro Arias Vasquez4,5

1Department of Cognitive Neurosciences, Radboud university medical centre, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, the Netherlands
2Department of Anatomy, Radboud university medical centre, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, the Netherlands.
3Wageningen UR (University & Research); Laboratory of Microbiology, Wageningen, the Netherlands
4Department of Psychiatry, Radboud university medical centre, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, the Netherlands
5Department of Human Genetics, Radboud university medical centre, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, the Netherlands

Emerging evidence recognizes the importance of the gut microbiota in the gut-brain axis, and its influence on neurodevelopment and brain function. Changes in microbial composition affect brain function and might be useful to modify neurodevelopmental disorders, like attention deficit hyperactivity disorder (ADHD). We hypothesized that gut microbiota of persons with and without ADHD, when transplanted into mice, might differentially modify mouse behavior and brain function and/or structure. We investigated this by colonizing young, male, germ-free C57BL/6JOlaHsd mice with microbiota from individuals with and without ADHD. We collected mouse microbiota samples, and performed behavioral tests and MRI techniques to assess behavior, brain structure and function. Principal coordinate analysis (PCoA) showed a clear separation of microbiota from feces of mice colonized with ADHD and control microbiota. We found 31 genera, predominantly in Lachnospiraceae and Ruminococcaceae families, to differ in relative abundance between mice groups. Mice colonized with ADHD microbiota showed decreased resting-state fMRI-based functional connectivity between right motor and visual cortices. Additionally, gray and white matter integrity loss in hippocampus and right internal capsule was observed with diffusion tensor imaging. Furthermore, mice colonized with ADHD microbiota were more anxious in the open field test. These results may reflect potential underlying mechanisms behind the effects of the gut microbiota in neurodevelopmental disorders, especially as specific bacteria were correlated with the increased anxiety and the structural changes found in the brains of mice correspond to those reported to be altered in several neurodevelopmental disorders such as ADHD and autism spectrum disorder. Therefore, our findings may help to understand the mechanisms through which the gut microbiota is involved in the pathophysiology of neurodevelopmental disorders.
Imitating unfamiliar languages vs. accents: No acoustic evidence that people vary in “phonetic talent”

Mónica A. Wagner (m.wagner@donders.ru.nl), Mirjam Broersma b, James M. McQueen a,c, Kristin Lemhöfer a

a Donders Institute for Brain, Cognition and Behaviour, Radboud University
b Centre for Language Studies, Radboud University
c Max Planck Institute for Psycholinguistics

Why are some people better than others at acquiring a native-like accent in a non-native language? This question has led some researchers to propose that people vary in the general ability “phonetic talent” (e.g., [1]). If the construct of phonetic talent truly exists, one would expect that talented people would demonstrate an advantage with any new sound system they encounter. However, support for phonetic talent so far has come from studies showing that speech imitation ability is related to L2 pronunciation [2, 3]. Stronger evidence for phonetic talent would be provided by evidence that imitation ability in one completely unfamiliar sound system predicts imitation in another such system. Here we tested the strong claim of a general phonetic talent by using two imitation tasks: imitation of an unfamiliar language (L0) and an unfamiliar accent in the L1. Native Dutch speakers imitated words with target vowels in Basque (/a/ and /e/) and Greek-accented Dutch (/i/ and /u/). Performance on the tasks was assessed acoustically as distance from target vowel spectrally and in terms of duration. Spectral and durational analyses revealed no relationship between the success of L0 and L1 imitation. Our results thus offer no acoustic support for the concept of a general phonetic talent.
Attending internal representations decreases object identification in natural scenes

Charlotte de Blecourt

The phenomenon of “seeing less” while attending internal representations is well-known among the general public. However, most studies on the influence of attention on object recognition use artificial stimuli. We investigated the effect of internally and externally directed attention on the identification of objects in naturalistic scenes. To test this, eighteen participants viewed a stream of scenes presented for 300 ms each at irregular intervals. The external attention task forced participants to attend their environment by counting the number of mirror symmetrical images in the image stream. The internal attention task involves working memory maintenance. Participants are instructed to remember a scene and ignore the subsequent images. In half of the trials, participants reported the presence of four objects in the last image of the stream instead of the regular task. Object recognition was poorer when attending internal representations compared to external stimuli. This study increases the external validity of the internal and external attention distinction and of laboratory findings on the influence of directed attention on visual perception. Moreover, it gives way to the possibility of studying behavioural and physiological signatures of attention in the outside world.
Common neural and transcriptional correlates of inhibitory control underlie emotion regulation and memory control

Wei Liu¹, Nancy Peeters¹, Guillén Fernández¹, Nils Kohn¹

1. Donders Center for Medical Neuroscience (DCMN), Donders Institute for Brain, Cognition and Behaviour, Radboud University Medical Centre, The Netherlands

Inhibitory control is crucial for regulating emotions, and it may also enable memory control. However, evidence for their shared neurobiological correlates is limited. Here, we report meta-analyses of human neuroimaging studies on emotion regulation, or memory control, and link neural commonalities to transcriptional commonalities using the Allen Human Brain Atlas. Based on 95 published fMRI studies, we reveal a common role of the right inferior parietal lobule embedded in a frontal-parietal-insular network during emotion and memory control, which is similarly recruited during response inhibition tasks. Using the Allen Human Brain Atlas, we demonstrate that emotion regulation and memory control-related brain activity patterns are associated with transcriptional profiles of a specific set of “inhibition-related” genes. Gene ontology enrichment analysis of these “inhibition-related” genes reveal associations with glutamatergic synapse, neuropeptide-related activity, and risk for major psychiatric disorders as well as Parkinson’s disease. These findings facilitate our understanding of the neurobiological correlates of inhibitory control and may contribute to the development of novel brain stimulation and pharmacological interventions.
Attention-deficit-hyperactivity disorder (ADHD) is often associated with comorbid aggression and sleep disturbances. The sleep/wake cycle is under the control of the suprachiasmatic nucleus (SCN) of the hypothalamus. The SCN functions as the master circadian clock and secretes a number of hormones including melatonin and cortisol that affect the sleep/wake cycle and also modulate aggressive behaviour. In addition, disturbance in components of the circadian rhythm have been associated with ADHD. However, to date, no study has yet investigated the role of the circadian rhythm related to ADHD with comorbid aggression. For this, animal models are needed enabling the control and manipulation of different circadian rhythm components.

ADHD with comorbid aggression can be modelled in BALB/cJ mice that show increased aggression, anxiety-like behaviour and inattention compared to the genetically related BALB/cByJ substrain. In the present study we aim to investigate the role of the circadian rhythm on aggression. Here, aggressive behaviour of 12 BALB/cJ and 12 BALB/cByJ mice is assessed for five consecutive days in the resident-intruder paradigm and related to changes in circadian locomotor activity during a 12-hours light/12-hours dark cycle and during a 24-hours dark cycle for 10 days. In addition, as glucocorticoids are known to influence the sleep/wake cycle, we further want to assess their influence on aggression by taking corticosterone measurements shortly after the last aggressive interaction in the resident-intruder and compare them to basal measurements. Furthermore, corticosterone measurements are taken before, during and after restraint stress to measure the corticosterone stress-response and subsequent recovery.

Together these data can give important insight into how the different components of the circadian rhythm can influence aggression. This will help us in better understanding how disturbances in the sleep/wake cycle in patients might lead to aggression.