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Oral presentations

Visual Worlds, a research and creation programme of the Media Art School of Chalon-sur-Saône

Olivier Perriquet *,[1,2]

[1] Ecole Media Art du Grand Chalon – Ministère de la Culture et de la Communication – France
[2] Le Fresnoy - Studio National des Arts Contemporains – Ministère de la Culture et de la Communication – France

The research and creation programme "Visual Worlds", led by the School of Fine Arts of Chalon-sur-Saône, is an artistic study of vision, through the variety of its sensitive manifestations.

Drawing on the notion of umwelt, as defined by biosemiotics, this program aims to explore the sensory experiences that vision causes, the stories that these experiences generate or that accompany them, the worlds that they create, both in living beings and within artificial vision systems or in the interaction between each other.

One of the challenges of this project, animated by a significant number of guests from a variety of fields of knowledge and creation, is to enable, through artistic creation, an aesthetic, philosophical and historical approach to vision that nourishes a fruitful dialogue with scientific research.

Visual practices and their study traditionally focus on the notion of image, i.e. on a manifestation, whether real or virtual, that one seems to be able to hold at an objective distance. The methodological approach of Visual Worlds is that of the primacy of perception. Adopting an ecological approach to perception, i.e. bringing together in a cohabitation a diversity of vision regimes without common measure (of time, scale, space, spectrum, etc.), this research aims to reveal the multiplicity of visual experiences while at the same time celebrating this diversity.

In view of the silent transformations of the world, and in the first place those related to the rise of artificial intelligence and technological progress, to the evolution of (geo)political power dynamics, to the impending ecological catastrophe, this programme seeks to propose an alternative narrative that is neither a moral injunction nor an expression of fear, but simply an invitation to consider humans in a broader perspective through the relationships they maintain with their human and nonhuman environment and in a time that transcends their own lives.

Funded by the Ministry of Culture and starting this autumn for a period of three years, this project will result in an international artistic and theoretical achievement in the form of an exhibition and symposium to be held in the summer of 2022.

As the initiator of this project, I propose to present its guidelines using a few examples of artistic works, put into perspective of the corresponding scientific issues, in order to encourage the possibility of an inter-disciplinary exchange on these matters.

Project website: https://tiny.cc/mondesvisuels

Un modèle variationnelle d'influence achromatique

Edoardo Provenzi *,[1]

[1] Institut de Mathématiques de l'Université de Bordeaux – UMR 5251 CNRS – France

Le modèle d'induction achromatique de Wallach du 1948 a été repris en 2004 par Rudd et Zemach avec une formulation inspirée par l'algorithme Retinex de Land. Dans l'exposé je montrerais qu'il est possible de plonger une variante du modèle de Rudd et Zemach dans un cadre variationnel très générale, qui peut être appliqué aussi pour la modélisation de phénomènes cognitives. L'analyse de la reformulation variationnelle met en évidence l'importance du balance entre contraste et adaptation.

Disclosing visual illusions via neural dynamics: Wilson-Cowan-type models and the efficient representation principle

Marcelo Bertalmío [1], Luca Calatroni [*,2], Valentina Franceschi [3], Benedetta Franceschiello [4], Alexander Gomez-Villa [5], Dario Prandi [6]

[1] DTIC, Universitat Pompeu Fabra, Barcelona, Spain – Spain
[2] Centre de Mathématiques Appliquées - Ecole Polytechnique – Ecole Polytechnique, Centre National de la Recherche Scientifique : UMR7641 – France
[3] IMO, Université Paris-Sud, Orsay, France – Université Paris-Sud, Orsay, France – France
[4] FAA, LINE, Radiology, CHUV, Lausanne – Switzerland
[5] DTIC, Universitat Pompeu Fabra, Barcelona, Spain – Spain
[6] CNRS, L2S, CentraleSupelec, Gif-sur-Yvette, France – CNRS : UMR8506 – France

We discuss the reproduction of supra-threshold perception phenomena, specifically visual illusions, with Wilson-Cowan-type models of neuronal dynamics. In particular, we show that the Wilson-Cowan equations can reproduce a number of brightness and orientation-dependent illusions, and that the latter type of illusions require that the neuronal dynamics equations consider explicitly the orientation, coherently with the architecture of V1. Then, we consider a slight modification of the Wilson-Cowan equations which makes such model consistent with the efficient representation principle, showing that this new model is indeed capable of replicating more visual illusions than the original Wilson-Cowan formulation.

A low-vision assistive device using mixed reality to enhance face recognition

Josselin Gautier *,1,2, Nicolas Chleq 2, Pierre Kornprobst 2

1 University of California [Berkeley] – United States
2 Inria Sophia Antipolis - Méditerranée – Institut National de Recherche en Informatique et en Automatique – France

Today's approach in design of visual enhancement system for people with central vision deficits consists in either overlaying or enhancing contours, simplifying the visual content or magnifying subjects' central vision. Using a classical but untested (Peli transform) or a stylization technique (xDoG) in a real environment and scenario, we proposed to enhance selectively the face of people seen through a mixed reality system to help low-vision patient recognize, identify and interact with people. The algorithm has the capacity to adjust the enhancement to the detected faces' size and distance, hence maintaining a constant boost in the critical range of spatial frequency (incycle per face). Two AMD patients and one Stargart disease patient were invited to freely explore their surrounding and recognize printed celebrities faces while self-controlling the gain and frequency of their own preferred visual enhancement. Beyond qualitative positive feedback, the first patient did not improved his face recognition rate while the second systematically improved his recognition abilities. Our system performs at near real-time with a modest laptop computer using multithreading (without GPU porting). More tests are necessary to fully evaluate the significance of such devices designed for real life applications. Feedback from patients have been included at all stages of development and evaluation; providing perspectives in the design and usability of low vision assistive technologies.

Is High-Phi a global 3D motion effect?

Martin Bossard *[,1], Simon K. Rushton [1]

[1] Cardiff University - School of Psychology – United Kingdom

In 2013 Wexler and his colleagues demonstrated a visually remarkable phenomenon they called high-phi. When observers are exposed to a rotating motion pattern (an inducer) followed by non-coherent motion (a noise), an illusory jump is perceived. The illusory jump is different to a traditional aftereffect because the jump is large, brief, and the inducer needs to last only a fraction of a second. We were interested in nature of the high-phi effect, in particular, its relationship to 3D global motion (optic flow) processing. The original demonstration used textured surfaces, we first established it also works with random dots (yes). We then investigated whether (i) the process is global, we removed a portion (wedge) of the stimuli and tested for the effect in the unstimulated region (c.f. the phantom motion after effect) with a probe (yes); (ii) whether the effect occurs with radial motion as well as circular motion (yes); (iii) whether the effect stores, i.e. still occurs if there is a delay between the inducer and the probe (yes, over the period we have tested); (iv) whether the effect is speed tuned (no, in-line with the original report) and changes in direction as a function of the inducer duration (yes but); (v) whether the effect follows optic flow geometry, whether the magnitude of the effect increases with distance from the centre of rotation or the focus of expansion (yes but). We are currently exploring whether we can generate a stereo motion-in-depth version of the effect, and whether the magnitude of the effect decreases with the size of the stimuli (c.f. surround suppression). I will present an overview of our experiments and our findings to date.

Does the brain perform arithmetical computations with neurally embedded kinematic parameters?

Laurent Goffart [*,2,1]

[2] Centre Gilles-Gaston Granger – Aix Marseille Université : UMR7304, Centre National de la Recherche Scientifique : UMR7304 – France
[1] Institut de Neurosciences de la Timone – CNRS : UMR7289, Aix-Marseille Université - AMU – France

Based upon observations made in the cat, it was proposed that target motion signals are used to predict its future position so as to assure a spatial lead of gaze at saccade end, instead of attempting a precise capture of the target. However, behavioral investigations in macaques do not support this claim. In the non-human primate, primary (interceptive) saccades toward a target moving with a constant speed do not land ahead of the target. They either lag behind the target or they are accurate (Fleuriet et al. 2011), even when the saccade trajectory is unexpectedly perturbed by a brief microstimulation in the superior colliculus (Fleuriet & Goffart 2012). In fact, the landing position of saccades depends upon the target acceleration (Quinet and Goffart 2015). Saccades undershoot the target when it accelerates but overshoot it when it decelerates.
Regarding the neurophysiology, interceptive saccades were proposed to be the outcome of the summation of signals "computed" by two parallel neural pathways. One computation would estimate the location where the target first appeared whereas the other would calculate the subsequent target displacement amplitude from velocity signals. These computations would involve activity propagating through two distinct pathways, a cortico-colliculo-reticular pathway and a cortico-ponto-cerebello-reticular pathway. Thus, the latter stream of activity would be responsible for producing, in a predictive manner, the movement component required to orient gaze toward the future location of the target ("future" relative to the snapshot taken by the former stream).
Rather skeptical that kinematic parameters could be embedded within the brain activity and that massively distributed and recurrent neuronal networks would subtend human-like arithmetic computations, we re-examined this theory. We recorded the activity of saccade-related neurons in the superior colliculus with the aim to test whether the population bursting activity would also include cells coding for saccade vectors corresponding not only to the current location of the target but also to its future locations (Goffart et al. 2017). Thus, we found that during the saccade-related burst, the active assembly does not include cells whose firing codes for saccades toward future locations of the moving target. Instead, it consists of a population of neurons issuing a continuum of commands, ranging from those related to antecedent target locations to commands related to its current location. Regarding the cortico-ponto-cerebello-reticular pathway, we tested its contribution by inactivating one of its output nuclei, the caudal fastigial nucleus (Bourrelly et al. 2018). Like saccades toward a static target, the horizontal component of interceptive saccades became hypometric when directed toward the contralesional side and hypermetric when they were ipsilesional. The horizontal dysmetria depended on target velocity, but the use of accelerating or decelerating targets revealed that velocity was not the crucial parameter.
Altogether, our investigations lead to a viewpoint where basic intrinsic properties of the brain suffice to explain the generation of accurate visually-guided (saccadic and pursuit) eye movements without considering that kinematic notions would be embedded within the brain functioning and that the brain would perform arithmetic computations upon them (Goffart et al. 2018; Goffart 2019).

Large category-selective responses of populations of neurons in the human ventral occipito-temporal cortex emerge independently of low-level statistical image properties

Bruno Rossion *,[1], Corentin Jacques [2], Louis Maillard [3], Sophie Colnat-Coulbois [4], Jacques Jonas [3]

[1] CNRS, Université de Lorraine – UMR7039 – France
[2] UCLouvain – Belgium
[3] CHRU-Nancy, Service de Neurologie – UMR7039 – France
[4] CHRU-Nancy, Service de Neurochirurgie – UMR7039 – France

Visual categorization is thought to be supported by high-level visual regions of the human ventral occipito-temporal cortex (VOTC). While the factors driving VOTC category-selectivity remain unknown, recent neuroimaging studies using within-category visually homogenous image sets have emphasized the contribution of low-level visual properties of stimulus sets. However, these studies have used within-category homogenous stimulus sets, increasing differences between categories. Here we recorded direct (i.e., electrophysiological) neural activity from 3525 recording contacts implanted in the VOTC of 61 epileptic patients viewing highly variable natural images of objects presented at a periodic rate (6 Hz), with variable face images interleaved as every 5th image (1.2 Hz) (Rossion et al., 2015; Jonas et al., 2016). Face-selective responses were objectively quantified at the face stimulation frequency (1.2 Hz) and harmonics (2.4 Hz, etc.). 853 face-selective contacts (24%) were identified throughout the whole VOTC, with peaks of activity along the right lateral fusiform gyrus and anterior temporal sulci. Strikingly, even at a liberal statistical threshold, only two face-selective contacts (i.e., 0.002%) showed a response to the same stimulation sequences with phase-scrambled versions of the images preserving image energy. Moreover, response amplitudes for scrambled images were negligible. Finally, across all face-selective contacts, the amplitude of face-selective response in the scrambled condition did not predict the response in the intact condition (Pearson correlation r=0.067). These observations show that large category-selective responses of populations of neurons in the human VOTC emerge independently of low-level statistical image properties.

Contrast sensitivity for rapid face categorization among natural images

Yu-Fang Yang *,[1], Joan Liu-Shuang [1], Bruno Rossion [2], Valerie Goffaux [1,3,4]

[1] Research Institute for Psychological Science, Université Catholique de Louvain, Louvain-la-Neuve – Belgium
[2] Université de Lorraine, CNRS, CRAN, F-54000 Nancy – Université de Lorraine, CHRU-Nancy, Service de Neurologie, F-54000, France – France
[3] Institute of Neuroscience, Université Catholique de Louvain, Louvain-la-Neuve – Belgium
[4] Department of Cognitive Neuroscience, Maastricht University, Maastricht – Netherlands

Visual categorization is fundamental for making sense and interacting with our complex natural environment. Successful categorization requires discriminating between items from different categories (i.e. faces vs. objects), as well as generalizing across exemplars of the same category despite their high variability in appearance (e.g. faces of different sex, view, lighting, hairstyle, etc.). Visual categorization is therefore often assumed to be a high-level process invariant to low-level image properties, such as contrast. However, there is data showing that this is not always the case [1].
The present work investigates how contrast modulates human face categorization using an electroencephalographic (EEG) "sweep" frequency-tagging paradigm2. Observers viewed 1-minute sequences of naturalistic object images presented at a fast 12-Hz rate, with faces interleaved periodically every 8th stimuli (1.5 Hz). Throughout a sequence, stimulus contrast either increased or decreased logarithmically in 14 steps between 0.8% and 100% relative to background. Full-contrast image sequences (contrast at 100% without variation) were also shown in order to obtain reference baseline responses.

EEG responses at 12 Hz harmonics, reflecting general visual processing of the natural image sequence, emerged over medial-occipital channels at 2.4% contrast and reached the saturation point at around 50% contrast (i.e. same response magnitude as responses to full-contrast sequences). EEG responses at 1.5 Hz harmonics, specifically indexing high-level face categorization, projected over right occipito-temporal regions. They emerged at a contrast of 7.4% contrast, but saturated at only 15.6% contrast. These results suggest that while human face categorization requires more contrast information compared to general visual detection processes, and it is overall less contrast-sensitive as evidenced by its lower saturation point.

To confirm that these findings reflected genuine high-level face categorization rather than other stimulation factors (e.g. the periodicity of the face images, or their low-level image properties), we conducted a follow-up experiment with the same design as above but using contrast-negated images. Contrast negation is a well-known image manipulation that preserves the global image structure yet disproportionately impairs high-level face processing 3. We found that contrast negation drastically increased the contrast-sensitivity of the face categorization response (i.e. responses emerged at higher contrasts and required more contrast to reach the saturation point), while it only had a negligible effect on the general visual response.

These findings suggest that while visual processing leading up to categorization is very sensitive to contrast, high-level visual categorization mechanisms themselves are relatively more invariant.

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Linguistic variables modulate where the eyes move regardless of word boundaries: Evidence against word-based eye-movement guidance during reading

Françoise Vitu [*,1], Claire Albrengues [2], Frédéric Lavigne [2], Carlos Aguilar [3], Eric Castet [4]

[1] Laboratoire de psychologie cognitive – Aix Marseille Université, CNRS : UMR7290 – France
[2] Bases, Corpus, Langage – Université de Nice Sophia-Antipolis, CNRS : UMR7320 – France
[3] Amaris Research Unit, Biot – Aucune – France
[4] Laboratoire de Psychologie Cognitive – Aix-Marseille Université - AMU, CNRS : UMR7290 – France

It has long been assumed that saccadic eye movements during reading are driven in a top-down word-based manner. According to this hypothesis, saccades are invariably programmed towards the center of peripheral target words, as selected based on the (expected) needs of ongoing processing, while the variability in within-word landing positions exclusively reflects systematic and random errors. Here we challenged the word-based view by testing one of its strong predictions: that linguistic variables should only influence the likelihood of word skipping, but not where in the words the eyes land. Using a large corpus of eye-movement data collected while forty native-French speakers read a total of 316 pairs of sentences, we showed that the frequency and the predictability of words only mildly affected eye-movement behavior in comparison with word length and saccadic launch-site distance to the words' beginning. Yet, frequency and predictability overall influenced where the eyes initially landed regardless of word boundaries, affecting either the likelihood of word skipping or within-word landing positions, all depending on the words' length and eccentricity. Shorter and nearer words were more often skipped, and even more so as their frequency or their predictability increased. However, as word length increased, word-skipping rate became both smaller and less strongly affected by word frequency/predictability, while within-word landing positions, closer to the words' center, showed increasingly greater language-related variations. These findings provide a strong case against top-down word-based eye-movement guidance, by revealing that ongoing word-identification processes only modulate default saccade amplitude, as determined by bottom-up, non-word-based, visuo-motor processes.

Rapid adaptation of fixation distribution during sentence reading with central field loss and its role in reading performance : a mediation analysis.

éric Castet *,[1]

[1] laboratoire de psychologie cognitive (LPC) – CNRS : UMR7290 – Aix-Marseille Université - CNRS - Laboratoire de Psychologie Cognitive - UMR 7290 - Fédération de recherche 3C Site ST CHARLES - 3 Place Victor Hugo - 13003 Marseille, France

Age-related Macular Degeneration patients (288 million people worldwide by 2040) are blind in their central visual field and have thus great difficulty to read text. Reading with central field loss (CFL) relies on peripheral vision and requires adaptation of visuo-attentional and oculo-motor processes. It is still an open question whether reading performance depends on the systematic (or at least frequent) use of one specific portion of peripheral vision (often referred to as the Preferred Retinal Locus - PRL). To address this question, forty-four normally-sighted subjects read French sentences with a gaze-contingent artificial scotoma (a 10∘ disk centred on the fovea). They had to read with the "self-paced reading" technique allowing to display only one word (N) at a time while masking all other words with 'x' strings: in order to read, subjects had to unmask the adjacent word (N+1 or N-1) by using keyboard presses. Several experimental blocks were run over a period of about 2 hours. For each subject and block, a fixation heatmap was created by plotting fixation locations with respect to each word's centre. Reading speed was regressed on several characteristics of fixation maps (centroid, size, ...). Results show that reading speed correlates with the vertical coordinate of the distribution's centroid. Importantly, a statistical mediation analysis shows that improvement in reading speed between the first and the last block is partly mediated by this vertical coordinate. Consequences of these results for designing novel visual rehabilitation protocols are discussed.

Efficiency and deficiency of pure visual control of arm movements: an assessment with patients deprived of somatosensory feedback

Fabrice Sarlegna *,[1]

[1] Institut des Sciences du Mouvement Etienne Jules Marey – Centre National de la Recherche Scientifique : UMR7287, Aix Marseille Université : UMR7287 – France

Vision is key for the accuracy of daily actions as the visual system provides signals to the brain about the state of the environment as well as the body. Somatosensory (proprioception and tactile) signals also inform the brain about the state of the body. Thus, visual and somatosensory signals are used to control everyday arm movements, such as hitting the 'Send' button or grasping an object. The loss of somatosensory afferents in patients with sensory neuropathy results in motor impairments but offers an opportunity to study pure visual control of arm movements.
Our recent studies helped better characterizing the motor deficits of deafferented patients: we found that the loss of the rapid somatosensory feedback loop results in impaired visually-guided reaching (*Sarlegna et al. 2010; see also Sainburg et al. 1995)* and impaired object manipulation (*Cuadra et al. 2019 ; Miall et al. 2019* ; see short videos https://www.youtube.com/watch?v=QK0EryOV6LE and https://www.youtube.com/watch?v=4lllTKtV7cY&t=10s). Thus, visual feedback cannot fully offset a massive somatosensory loss for the execution of fine arm and hand motor skills, which require a high degree of precision. In contrast, we observed that visual feedback can compensate for a massive somatosensory loss to adapt, trial-by-trial, the control of arm movements as deafferented patients can adapt as well as controls to new (prismatic) glasses or a new force field (*Lefumat et al. 2016 ; Miall et al. 2018*). From these results, one might infer that in healthy individuals, somatosensory signals are key for the rapid feedback control of fine motor skills. When the timescale is less constrained and the task less difficult, only visual feedback, or only somatosensory feedback, seems sufficient to efficiently update, trial after trial, an existing control policy (*Sarlegna et al. 2010; Lefumat et al. 2015*).

Overall, our findings highlight the flexibility of the sensorimotor system which can maintain its adaptive property at the greatest level in various contexts (e.g., in complete darkness or with a sensory neuropathy). However, visual and somatosensory signals offer specific features such that each sensory system cannot systematically compensate for deficits in the other sensory system.

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An Eye Saccade Related Potential analysis of the motion perception during saccadic eye movements

Anne Guérin Dugué *,[1], Adrien Rabier [1], Bastien Faure-Brac [1], Violette Allam [1], Eric Castet [2]

[1] Grenoble Images Parole Signal Automatique – Institut Polytechnique de Grenoble - Grenoble Institute of Technology, Centre National de la Recherche Scientifique : UMR5216, Université Grenoble Alpes – France
[2] Laboratoire de psychologie cognitive – Centre National de la Recherche Scientifique : UMR7290, Aix Marseille Université : UMR7290 – France

It is well known that the visual perception is modified before, during and modulated during the saccade. In 2000, Castet and Masson showed that the visual processing of moving stimuli during saccades is active and functional whereas the common belief is that information processing during saccades would be actively suppressed by an extra-retinal signal. In this study, the princeps experiment proposed by Castet and Masson was replicated but with a co-registration of EEG and eye movements. Data from seventeen healthy adults participated in the experiment. Data from two participants were discarded, one due to a misunderstanding of the task and the other one due to too noisy EEG signals. On each trial, a moving grating of low spatial frequency (0.17cy/$\circ$) and high temporal frequency (360$\circ$/s) was displayed. For a horizontal saccade, in the same direction of the stimulus, the motion perception was possible if the peak velocity of the eye was sufficient. For each trial, at the apparition of a visual cue, the participant had to make a horizontal saccade with a specific size, and then indicate his/her perception or not of the stimulus motion. For the condition of interest (STIM), the spatial orientation of the grating was vertical and motion direction was horizontal from left to right. For the control condition (CTRL), the participant realized the same saccade but with an orthogonal stimulus. Thus the stimulus motion could not be perceived whatever the saccade size. Two evoked potentials were analyzed, the first one at the visual cue onset, and the second one at the saccade onset. These two potentials were estimated by a General Linear Model to take into account their temporal overlap. Three configurations were compared: STIM depending of the motion perception, and CTRL without motion perception. As expected, no differences were observed for the evoked potential at the visual cue onset, whereas significant differences were observed on the evoked potential at the saccade onset for the configuration STIM with motion perception compared to the two others which were not significantly different from each other. Notably, this difference took place from 120 ms after the saccade onset in posterior areas. And after sources localization, the neural activity in left angular gyrus, containing MT/V5 area shown a clear differentiation between the condition STIM with motion perception compared to the two others, from 120 ms after the saccade onset. To conclude, these results show an activation of the visual magnocellular pathway of the motion perception done during the saccade.

Counter-intuitive integration of visual priors: Insights from a decision-making task.

Federica Conti *,[1], Anna Montagnini [1]

[1] Institut de Neurosciences de la Timone – Aix Marseille Université : UMR7289, Centre National de la Recherche Scientifique : UMR7289 – France

The study of decision-making is undoubtedly one of the most widely explored areas of vision science. In this framework, we implemented a new variant of a Random Dot Kinematogram decision task, whereby participants were not constrained to keep central fixation during the RDK display. The eye movements of thirteen healthy volunteers have been recorded during the whole duration of the decision task, both in equiprobable conditions and in the presence of a strong bias (90%) favoring one of the alternative outcomes. Task difficulty varied over four distinct coherence levels, namely, 0.05, 0.10, 0.20 and 0.40. Subjects' answers were communicated via a saccade towards one of two targets displayed at a 45○ angle from the corresponding motion direction. Behavioural results show that, generally, in the early phase of RDK display, smooth eye movements velocity is directly proportional to motion coherence. Moreover, an analysis of the pre-saccadic epoch reveals that for many subjects (but not all) decision accuracy (correct vs incorrect trials) could be predicted above chance based on the average smooth velocity. Most interestingly, however, quite unexpected is the overall effect of the direction bias, as demonstrated by a significantly higher error rate, and a frequently slower reaction time with respect to the unbiased condition. Very weak or no oculomotor anticipation was observed in the biased condition, whereas smooth eye movements during the RDK motion epoch were generally coherent with the behavioral performance, including in the frequent error trials.

Are saccades influenced by unconscious stimuli ?

François Stockart *,[1], Claire Sergent [2], Thérèse Collins [3]

[1] Integrative Neuroscience and Cognition Center – Université Paris V - Paris Descartes, Centre National de la Recherche Scientifique - CNRS : UMR8002 – France
[2] Laboratoire Psychologie de la Perception (LPP) – Université Paris Descartes - Paris 5 : UMR8242, Centre National de la Recherche Scientifique : UMR8242 – Centre Biomédical des Saints Pères 45 rue des Saints Pères 75270 Paris cedex 06, France
[3] Laboratoire Psychologie de la Perception – Université Paris Descartes - Paris 5 : UMR8242, Centre National de la Recherche Scientifique : UMR8242 – France

We examined whether unconscious stimuli (i.e. stimuli that participants report not having seen) influence saccade metrics. We exploited the global effect, a phenomenon in which saccade amplitude is pulled towards a distractor that appears in the spatial vicinity of a saccade target (Findlay, 1982; Walker, Deubel, Schneider, & Findlay, 1997). Using adaptation-induced blindness (Motoyoshi & Hayakawa, 2010), we devised an experiment in which a distractor with a strong contrast could be either seen or unseen, and examined the influence of the distractor on saccades to a nearby target. A global effect was observed in the condition in which the distractor was perceived, but not in the condition in which the distractor was not perceived. Surprisingly, these drastically distinct effects of seen and unseen distractors were observed even when the stimulation itself was strictly identical in both cases. These results suggest that the conscious status of a stimulus determines how this stimulus influences saccades. Previous litterature on adaptation-induced blindness suggests that, even when the distracteur is not seen, it might nevertheless be represented in V1. The present results would thus indicate that the representation of unseen distractors is suppressed before reaching the superior colliculus, in which competing object represention are thought to code for saccade metrics (Findlay & Walker, 1999). In a second forthcoming experiment, we plan to verify that the unconscious distractor is represented in V1 by testing if it is subject to the tilt illusion.

Interlimb transfer of visuomotor prismatic adaptation in patients with corpus callosum abnormalities

Penelope Tilsley *[,1], Patricia Romaiguère [2], Eve Tramoni-Negre [3], Olivier Felician [3], Fabrice Sarlegna [4]

[1] Institut des Sciences du Mouvement (ISM) – Aix-Marseille Université - AMU – France
[2] Institut des Sciences du Mouvement (ISM) – Aix-Marseille Université - AMU, Centre National de la Recherche Scientifique - CNRS – France
[3] Institut de Neurosciences des Systèmes (INS) – Aix-Marseille Université - AMU, Hôpital de la Timone [CHU - APHM] – France
[4] Institut des Sciences du Mouvement (ISM) – Aix-Marseille Université - AMU, Centre National de la Recherche Scientifique - CNRS – France

When humans adapt with one limb to a perturbation such as a force-field or visuomotor perturbation, this adaptation can generalize to a different workspace, or even to the opposite limb. Such generalization across limbs is known as interlimb transfer, and despite being well documented in the literature, there are still questions surrounding the underlying neural mechanisms (Ruddy & Carson 2013). Several theoretical models highlight the corpus callosum as a potential key structure for mediating transfer (Taylor & Heilman 1980; Parlow & Kinsbourne 1989), however select research on force-field adaptation in a corpus callosum split-brain patient has contradicted this (Criscimagna-Hemminger et al. 2003). Research on cerebellar patients has shown however that, at the level of the cerebellum, the mechanisms underlying visuomotor and force-field adaptation are distinct (Rabe et al. 2009). As the mechanisms between these different types of adaptation seemingly differ, it is not so clear whether visuomotor adaptation would also transfer between the limbs in corpus callosum patients. We therefore aimed to study interlimb transfer of visuomotor prismatic adaptation from dominant to non-dominant arm, but also from non-dominant to dominant arm, in a range of patients with corpus callosum injury and matched controls. Based on the models involving the corpus callosum as a key brain structure mediating interlimb transfer, it would be hypothesized that these patients should not show interlimb transfer of visuomotor adaptation in either direction. Results from two patients with recent naturally acquired lesions of the corpus callosum and one agenesis patient have demonstrated clear visuomotor adaptation of the arm exposed to the prismatic goggles. Further, results indicate significant interlimb transfer from the dominant to the non-dominant arm, but also from the non-dominant to the dominant arm. These results raise questions as to the neural mechanisms of interlimb transfer of visuomotor adaptation, with discussions lending themselves to the role of the ipsilateral hemisphere in motor control, transfer of visuomotor maps and information transfer via the splenium.

Integration and comparision of visual and working memory representations in posterior parietal cortex

Guilhem Ibos *,1

1 Institut de Neurosciences de la Timone – Aix Marseille Université : UMR7289, Institut National de la Santé et de la Recherche Médicale : UMR7289, Centre National de la Recherche Scientifique : UMR7289 – France

Everyday, we face the challenge of making decisions based on different sources of information. For example, detecting a friend in a crowed environment requires to compare sensory information (what we are looking at) to mnemonic representation (what we are looking for). Deciding whether what we are looking at matches what we are looking for is a complicated task. In a series of experiments (Ibos & Freedman, 2014, 2016, 2017), I've tested how neurons from lateral intraparietal area (LIP) of non-human primates (NHP) are involved in such comparative process. I show that LIP multiplex representation of all the relevant information required to solve this task and propose a new framework for the role of Posterior Parietal Cortex (Freedman & Ibos 2018).
Specifically, NHPs were trained to perform a delayed-match to sample task in which they had to compare the identity of test stimuli to the identity of a previously shown sample stimulus. In this context, LIP neurons multiplex sensory, mnemonic and decision-related representations. Specifically, LIP neurons sequentially process and multiplex the information required to perform this task:

First, LIP neurons express selectivity to the identity of the stimulus NHPs are looking for and which is kept in working memory in a manner consistent with the integration of top-down signals originating in the prefrontal cortex. This allows LIP neurons to encode the identity of stimuli monkeys are looking for.

Second, LIP neurons are also selective to sensory information, reflecting the integration and the biding of bottom-up flows of sensory signals (previously gated by top-down attention). This allows LIP neurons to encode the identity of the stimuli monkeys are looking at

Third, LIP neurons encode the match/non-match status of the stimuli, suggesting that LIP neurons participate to the decison-making process.

Interestingly, the encoding of sensory information precedes decision-related representations in LIP. This sequential processing suggests that LIP plays a specific role in the comparison of sensory and cognitive representations.

However, we still lack a computational framework which would validate LIP's putative role in such comparative decision-making. In addition to the experimental evidence, I will present, as proof of concept, a spiking neural network (SNN) based on LIP neuronal activity during a delayed conjunction matching task. It will demonstrate LIP's matching discrimination capacity based on the integration of both sensory and cognitive information.
Specifically, I test that non-uniform distributions of synaptic weights and delays inside given groups of excitatory and inhibitory neurons create a spectrum of selectivity to the identity and the match status of the stimuli. Neurons from this SNN multiplex bottom-up sensory and top-down cognitive

information as well as robustly encode the match status of the stimuli, reproducing previously presented experimental results.
This study demonstrates that biologically plausible organization could mimic LIP neuronal activity and confirms LIP's putative role in comparative decision-making.

Processing of rotational symmetry in the non-human primate brain

Pauline Audurier *,[1], Benoit Cottereau [2]

[1] Centre de recherche cerveau et cognition (CERCO) – CNRS : UMR5549, Université Paul Sabatier (UPS) - Toulouse III – France

[2] Centre de recherche cerveau et cognition (CERCO) – CNRS : UMR5549, Université Paul Sabatier (UPS) - Toulouse III – CHU Purpan - Pavillon Baudot BP 25202 31052 Toulouse Cedex, France

Symmetry is a highly salient feature of the natural world that is specifically processed by numerous species of the animal kingdom and notably by primates. Previous neuroimaging measurements have identified several visual areas (in particular along the ventral pathway) that have selective responses to reflection symmetry in humans and to a lesser extent in macaques. Here, we wanted to determine whether another form of symmetry - rotational symmetry - is also processed by both primate species. We adapted the experimental protocol from a previous human fMRI study to characterize BOLD responses to rotational symmetry in rhesus macaque. Recordings were performed at 3T in two awake monkeys using a dedicated 8-channel coil positioned above the animal's head. We used a block design where the stimuli alternated between a baseline (i.e. fixation point only), a sequence of textures that contained rotational symmetry and a sequence of control textures that shared the same low-level features but had no rotation symmetry. The rotation symmetry textures were exemplars from one of four distinct classes, interleaved between the runs. These classes differed on the maximum order of rotation symmetry (i.e. the number of rotations that leave the pattern unchanged) they contained: 2, 3, 4 or 6. Eye movements were monitored while the monkey performed a fixation task. We only analyzed runs where fixation was confirmed for more than 85% of the time. Sixteen and twenty valid runs were collected for each symmetry order in the first and second macaques, respectively. From a general linear model computed using SPM 12 and that included saccadic eye movements and motion related noise signals as regressors of non-interest, we found that all the symmetry conditions led to significantly stronger responses than their respective control in areas V3 and V4, as well as in more anterior regions along the lower bank of the superior temporal sulcus (STS). Responses in all these regions depended parametrically on the maximum order of rotation symmetry in the stimuli, with higher symmetry orders leading to stronger activations.These properties are strikingly similar to those observed in humans using the same protocol. Altogether, our results suggest that the cortical networks that process rotational symmetry in human and macaque are at least partially homologous.

Multisensory integration in the posterior cingulate gyrus in macaque at local field potentials level

Anne-Laure Vittek [*,1], Cécile Juan , Pascal Girard [2,3,4], Manuel Mercier , Céline Cappe [5]

[1] Cerco – CNRS : UMR5549 – France
[2] CerCo – CNRS : UMR5549 – Pavillon Baudot CHU Purpan BP 25202 31052 Toulouse Cedex 03, France
[3] Université Paul Sabatier – Université Paul Sabatier-Toulouse III - UPS – 118 Route de Narbonne, 31400 Toulouse, France
[4] INSERM – Institut National de la Santé et de la Recherche Médicale - INSERM – Pl. du Docteur Joseph Baylac Toulouse Cedex 3, France
[5] Centre de recherche cerveau et cognition (CERCO) – Université Paul Sabatier - Toulouse 3, Centre National de la Recherche Scientifique : UMR5549 – CHU Purpan - Pavillon Baudot BP 25202 31052 Toulouse Cedex, France

Many cerebral areas are known to be involved in multisensory integration. Although the posterior cingulate gyrus (PCG) has connections with some of these areas, for example the superior temporal sulcus and some thalamic nuclei (including the medial pulvinar), its involvement in multisensory processing hasn't been studied so far. This area is known to be involved in spatial orientation and monitoring of eye movements, and to be sensitive to visual stimulations. However, nothing is known about auditory and audiovisual processing. We here recorded local field potentials in the posterior cingulate gyrus in response to auditory, visual and audiovisual stimulation in two awake macaque monkeys during a passive fixation task. Monkeys had to maintain fixation on a central point of a screen during the presentation of a visual stimulus, listening to an auditory stimulus or both together. Local field potentials were then analyzed, for their amplitude and frequency content. Two models were computed to test for multisensory integration: the additive one, which is the sum of the visual and auditory local field potentials, and the maximum one, which corresponds to the modality with the strongest response at each timepoint. For frequency content, two analyses were performed. First, fast Fourier transform for the stimulus epoch, between 8 and 200 Hz and time-frequency analysis for some band of frequencies (β 12-30 Hz, low γ 30-80 Hz and high γ 80-170 Hz). First, our results confirm PCG activity in response to visual stimulation. Second, they reveal that PCG also responds to auditory stimulation. Indeed, we observed evoked potential in these two conditions, different from the baseline. Third, they show that this area is involved in multisensory processing, for two reasons. Audiovisual evoked potentials are different from auditory and visual evoked potentials. Moreover, the comparison with the two models reveals some differences, and the amplitude is higher for the audiovisual condition than predicted by the models. Fourth, spectral analyses provide information about frequency content of the evoked potentials. It shows differences in the power of some frequencies between audiovisual and visual conditions, mostly in low frequencies (8 ; 12 ; 16 and 120 Hz). Time-frequency analysis reveals that high frequencies (30-170 Hz) are needed for visual and audiovisual processing but not for auditory processing, as these frequencies are absent in the auditory condition. Altogether our study shows that the posterior cingulate should be considered as a multisensory structure.

Chronic neural adaptation to habitual optical blur alters neural processing

Antoine Barbot *,[1,2], Geunyoung Yoon [2]

[1] Spinoza Centre for Neuroimaging, Amsterdam – Netherlands
[2] University of Rochester Medical Center – United States

Understanding the limits of human vision requires fundamental insights into the contributions of both optical and neural factors. The eye's optics are far from perfect, degrading retinal image quality by reducing contrast and disrupting the phase of transmitted spatial frequency (SF) information. Yet, the contributions of optical factors to neural processing are largely underappreciated. Specifically, how neural processing is altered by the long-term exposure to habitual optical blur has remained unexplored. Answering this question is important for understanding capacity for and limits of visual plasticity in the adult brain. Here, I will present a series of study in which we investigated the mechanisms by which prolonged, chronic exposure to optically degraded visual inputs alters neural processing in typically-developed adults with keratoconus (KC)–a severe and progressive corneal disease.
In a first set of experiments, we characterized the impact of chronic exposure to habitual optical aberrations on the contrast sensitivity function (CSF). Using adaptive optics (AO), we were able to bypass optical factors and measure visual processing under aberration-free conditions. Our results reveal a large-scale reorganization of neural sensitivity following long-term exposure to poor ocular optics. Under similar AO-corrected optical conditions, KC participants showed altered CSF relative to neurotypical controls, with impaired sensitivity for high spatial frequencies (SF) and poorer visual acuity. Interestingly, KC participants also showed enhanced sensitivity to low-SF information relative to controls. The more severe the habitual optical aberrations experienced in everyday life, the more pronounced were the alterations in sensitivity under AO correction. Using the equivalent noise paradigm, we showed that improved low-SF sensitivity and impaired high-SF sensitivity reflected lower and higher levels of internal noise, respectively. These findings support the notion that the CSF reflects an optimal allocation of the brain's limited sensory resources. In this context, the pattern of gains and losses in sensitivity we observed reveals the existence of neural compensation mechanisms that optimize the brain's limited sensory resources to the structure of the degraded retinal inputs via SF-specific changes in gain.

In another series of experiments, we explored the impact of blur-induced shifts in spatial phase on perceived phase congruency using visual psychophysics and AO. We found that humans are sensitive to both physical phase shifts and blur-induced alterations of phase congruency. In the presence of AO-induced optical aberrations, the magnitude and direction of perceived phase shifts matched predictions from optical theories. Moreover, these perceived phase shifts decreased with time during short-term adaptation to AO-induced blur, and were followed by brief after-effects in the opposite direction once returning to fully-corrected optical quality. These findings reveal the existence of neural compensation mechanisms to phase spectra that partially restore phase congruency over time. Consistent with this idea, KC patients with severe habitual optical aberrations showed altered phase congruency relative to neurotypical observers when tested under aberration-free AO condition.
Altogether, the present findings uncover fundamental properties of adaptive neural mechanisms in the adult visual system that compensate for optically-related sensory loss in an optimal way.

Dissociation between objective and subjective perceptual experiences in a population of hemianopic patients: A new form of blindsight?

Clémentine Garric [*,1,2], Aïda Sebaa [2], Florent Caetta [2], Céline Perez [2], Julien Savatovsky [3], Claire Sergent [4], Sylvie Chokron [2,4]

[1] Sciences Cognitives et Sciences Affectives (SCALab) - UMR 9193 – Université de Lille, Centre National de la Recherche Scientifique : UMR9193 – France

[2] Unité Vision et Cognition – Fondation Ophtalmologique Adolphe de Rothschild [Paris] – France

[3] Service d'Imagerie – Fondation Ophtalmologique Adolphe de Rothschild [Paris] – France

[4] Laboratoire Psychologie de la Perception – Université Paris Descartes - Paris 5 : UMR8242, Centre National de la Recherche Scientifique : UMR8242 – France

After a post-chiasmatic lesion, some patients may retain unconscious visual function, known as blindsight, in their contralesional visual field. Despite the importance of blindsight in the study of consciousness, little is known about the nature of patients' experience in their hemianopic field. To address this knowledge gap, we measured blindsight, and assessed the perceptual experience in the contralesional visual field, of seventeen homonymous hemianopic (HH) patients. To ensure that the stimuli were shown in a "blind" sector of the visual field, we selected a subgroup of eight complete-HH patients, as determined by automatic perimetry. Firstly, we measured blindsight through a forcedchoice task in which the patients had to identify letters displayed on a screen. Secondly, we compared the patients' binary responses ("Something was presented" vs "Nothing was presented") to responses on a new, five-level scale, the Sensation Awareness Scale (SAS), which we designed to include visual as well as non-visual answers (e.g., "I felt something"). Interestingly, only one of the eight complete-HH patients met the criteria for blindsight. More importantly, our SAS enabled us to identify a previously unreported dissociation, which we have named blindsense, in four of the eight complete-HH patients. Specifically, these four patients exhibited better-than-chance sensitivity to the presence of a stimulus on the subjective scale, despite being unable to identify the stimulus during the forcedchoice task. Our findings highlight the importance of awareness-assessment methods to investigate perceptual experiences in the contralesional visual field and suggest a low incidence of blindsight in post-stroke HH patients.

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