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ABSTRACT

♦ **An objective signature of illusory surface perception as evidenced by EEG frequency-tagging**
1 **of the Kanisza square figure**

N Alp[1], N Kogo[1], G Van Belle[2], J Wagemans[1], B Rossion[2] ([1]University of Leuven; [2]Université Catholique de Louvain)

Over a hundred years after Wertheimer's seminal work, the question of how a Gestalt arises in the visual system remains unanswered. Here we applied high-density electroencephalography (EEG) together with the technique of frequency tagging (Regan & Heron, 1969) to define an objective trace of a Gestalt in the visual system. Specifically, by using the Kanizsa square figure, we tracked the emergence of an illusory surface. In the "experimental condition", four pacmen were placed to form an illusory square. In the "control condition", the four pacmen were rotated in arbitrary angles so that the illusory surface disappeared. The two diagonal pacman pairs were 100% contrast-modulated at different frequency rates (f1 = 3.57 and f2 = 2.94 Hz) for 13 seconds. Fourier transform of the EEG recordings (12 participants) showed robust low-level responses specifically at these fundamental frequency rates, which did not differ between conditions. Most importantly, strong nonlinear intermodulation (IM) components (eg, $3.5714 - 2.9412 = 0.6302$) appeared in response to the illusory figure. These IMs can only be produced by neuronal populations that integrate the two stimulations nonlinearly (eg, Boremanse et al., 2013), and they were only present in the experimental condition where all the parts (pacmen) are integrated coherently to form an illusory surface. Moreover, changing the support ratio influenced the amplitude and the distributions of IMs, but not the fundamental frequencies. These results indicate that IM components in EEG provide a neural signature of Gestalt configurations.

♦ **Using EEG to investigate visual symmetry perception**
2 M Bertamini, A Makin (University of Liverpool)

In a number of recent studies we have explored visual symmetry processing by measuring event related potentials and neural oscillatory activity. Here we summarise the answers that we can now provide to seven different questions. (1) There is a sustained posterior negativity (SPN) related to the presence of symmetry (Hofel & Jacobsen, 2007). Is the SPN automatic? Answer: Yes, it is always present, and this supports preattentive symmetry processing. (2) Is the SPN generated in extrastriate visual cortex, and is it therefore the electrophysiological correlate of fMRI activation (Sasaki et al. 2005)? Answer: Yes. (3) Is the SPN unique to reflection? What about other regularities? Answer: Greatest for Reflection but present for other regularities. (4) Does it matter whether symmetry is present in an object, as opposed to a ground region? Answer: No. (5) Is the SPN generated by symmetry independent of view angle? Answer: Present for slanted symmetry, but slant compensation is not automatic. (6) Does symmetry processing affect neural oscillations and thus produce alpha desynchronization? Answer: Symmetry/ random discrimination tasks produce greater alpha desyncrhonization over the right hemisphere. (7) Does symmetry processing produce an automatic emotional response? Answer: No, but discovering symmetry is affectively positive.

♦ **Perifixational compression of space through masking: two references, two-dimensional**
3 **mislocalization**

S Born[1], E Zimmermann[2], P Cavanagh[1] ([1]Laboratoire Psychologie de la Perception, Université Paris Descartes; [2]Institute of Neuroscience and Medicine 3, Research Centre Jülich)

Previous research has reported dramatic localization errors around the time of an eye movement. For instance, stimuli briefly flashed just before or after a saccade are perceived to be closer to the saccade target (Ross, Morrone, & Burr, 1997). This phenomenon is known as saccadic compression of space. In a series of experiments, we have demonstrated that similar distortions of space (Zimmermann, Fink, & Cavanagh, 2013) can be found in the absence of eye or image motion: Brief probes were attracted toward a visual reference when followed by a mask. We extend these studies to examples with a pair

Note: These abstracts have not been edited and are printed as submitted.

of references that draw the probe into the gap between them. Strong compression was found when we presented the reference stimuli followed by the mask, whereas little or no compression occurred for either the reference pair or the mask alone. When the two references were aligned vertically, probes were attracted to the center point between the two references. However, when the two references were aligned horizontally, probes were attracted to the left reference, irrespective of whether the stimuli were presented left or right of fixation. We suggest that compression can be explained in terms of summation of neural activity distributions. The possible role of attention, apparent motion and mechanisms computing the likely offset between corresponding objects will also be discussed.

♦ **Drawing on the right side of the brain: A voxel-based morphometry study of individual**
4   **differences in drawing and local processing ability**
R Chamberlain[1], C McManus[2], N Brunswick[3], R Kanai[4] ([1]University of Leuven; [2]University College London; [3]Middlesex University; [4]University of Sussex)
The relationship between individual differences in brain structure and expert abilities has been demonstrated in a number of domains including visual perception, spatial navigation, complex motor skills and musical ability. However research into neural differences associated with skill in visual art is scarce. The aim of this study was to investigate whether there were any differences in brain structure in relation to increasing representational drawing skill in a diverse group of training artists. The relationship between brain structure and drawing skill was then examined in relation to local perceptual processing abilities in order to explore existing behavioral evidence that local processing facilitates drawing ability (Drake & Winner, 2011; Chamberlain et al, 2013). A cohort of graduate and post-graduate art students and non-art students completed drawing tasks, the embedded figures task and the block design task. Scores on these tasks were then correlated with the regional grey and white matter volume in cortical and subcortical structures. An increase in grey matter density in the cerebellum was observed in relation to observational drawing ability which was independent of artistic training, suggesting an enhancement of fine motor control and procedural memory. Furthermore, overlap in medial frontal regions associated with performance on local processing tasks and drawing suggest that drawing may be facilitated by the suppression of bias toward global perceptual processing in action selection. The findings corroborate small-scale fMRI studies of online drawing and provide insights into the properties of the developing artistic brain.

♦ **Visually aware referring expression generation**
5   A Clarke[1], H Rohde[1], M Elsner[2] ([1]University of Edinburgh; [2]Ohio State University)
Referring expression generation (REG) is a linguistic task in which the speaker has to produce a description of the target object so that a listener can find it quickly and accurately. This problem has been studied in psycholinguistics and natural language processing with the perceptual aspect being largely overlooked: vision is treated as a pre-process where speakers pre-attentively extracts all relevant feature categories for each object in the scene. We present results from two experiments that demonstrate that taking visual features into account allows us to better predict the content of the referring expressions our subjects produce. In the first study, we investigate how visual properties (salience, clutter, area and distance) influence REG using images from the "Where's Wally?" books. We find that referring expressions for large salient targets are shorter than those for smaller, less salient targets. The choice of spatial relations and the order in which landmarks are mentioned also appear to be influenced by visual properties. This is followed by an eye-tracking study using more controlled stimuli in which we show that concepts from visual search can help explain variation in the onset to speech time. Whereas previous results in the REG literature concludes that onset to speech times linearly increase with set size, we show that this is not the case when the target is a unique shape against a homogeneous array of distracter items, ie, when it "pops out". Our work suggests that previous models of REG fail to scale to visually complex scenes.

♦ **The development of the Leuven Embedded Figures Test (L-EFT)**
6   L de-Wit, J Degroef, R Van der Hallen, J Wagemans (University of Leuven)
The Embedded Figures task has a long history as an important clinical and psychological test. There is however some ambiguity as to what exactly the test measures. This ambiguity is brought into clear focus by the fact that some researchers use the test as a measure of a local or global perceptual bias while others regard the test as a good measure of a much broader cognitive capacity related to intelligence or executive function. Given the importance of this test, particularly in clinical domains such as Autism, we have set out to develop a new version of the embedded figures test that more

systematically manipulates the perceptual factors that contribute to the effective embedding of a target in a complex context. The result from two experiments will be presented, in which a range of factors, including continuity, complexity, closure and symmetry are revealed as potentially important. Based on these two experiments, a new set of stimuli will be presented which will form the basis of our new version of the Embedded Figures Test, which we plan to launch as an online test using the format of the Leuven Perceptual Organization Screening Test (L-POST). By more systematically manipulating the perceptual factors that contribute to effective embedding, we hope to offer a much more sensitive test, and a test that is better able to differentiate between genuine perceptual, as appose to executive, contributions to performance on this test.

♦   **On the applications of amodal completion in stage magic: From good continuation**
7   to volume completion and beyond

V Ekroll, B Sayim, J Wagemans (Laboratory of Experimental Psychology, University of Leuven)
We argue that the essence of a magical experience—ie the illusion of impossibility—is a duality of experience in which the spectator maintains two conflicting beliefs which are both too strong to be doubted. Considering that humans generally tend to believe most strongly in (a) what they see and (b) the laws of nature, creating the illusion of impossibility essentially amounts to exploiting any erroneous assumptions about either the former or the latter. Thus, huge gaps between what we actually perceive and what we intuitively believe we are able to perceive ("failures of visual meta-cognition") provide an excellent, perhaps even the ultimate, tool for producing a strong magical experience. Most previous academic research on the psychological principles of magic has focused on the failures of visual meta-cognition associated with misdirection, change blindness and inattentional blindness. Here, we argue that another systematic failure of visual meta-cognition, namely that associated with amodal completion and amodal presence, plays an important role in the creation of many magical effects. We present several different examples that illustrate the crucial role of known principles of amodal completion in stage magic. Conversely, we illustrate how some simple, yet surprisingly potent magical tricks may point to the existence of phenomena related to amodal completion which are still largely unexplored in academic psychology.

♦   **fMRI correlates of object-based attentional facilitation versus suppression of irrelevant**
8   stimuli

E Freeman[1], E Macaluso[2], G Rees[3], J Driver[3] ([1]City University; [2]Santa Lucia Foundation; [3]University College London)
Two popular assumptions, within theories of object-based attention, are that attentional resources are facilitatory and that they spread automatically within grouped objects. Consistent with this, ignored visual stimuli can be easier to process, or more distracting, when perceptually grouped with an attended target stimulus. But typically, the ignored stimuli share potentially relevant features or locations with the target. In this fMRI study, we measured the effects of attention and grouping on Blood Oxygenation Level Dependent (BOLD) responses in the human brain to entirely task-irrelevant events. Two checkerboards were displayed each in opposite hemifields, while participants responded to check-size changes in one pre-cued hemifield, which varied between blocks. Grouping (or segmentation) between hemifields was manipulated between blocks, using common (versus distinct) motion cues. Task-irrelevant transient events were introduced by randomly changing the colour of either checkerboard, attended or ignored, at unpredictable intervals. The above assumptions predict heightened BOLD signals for irrelevant events in attended versus ignored hemifields for ungrouped contexts, but less such attentional modulation under grouping, due to automatic spreading of facilitation across hemifields. We found the opposite pattern, in primary visual cortex. For ungrouped stimuli, BOLD signals associated with task-irrelevant changes were lower, not higher, in the attended versus ignored hemifield; furthermore, attentional modulation was not reduced but actually inverted under grouping, with higher signals for events in the attended versus ignored hemifield. These results challenge the assumptions underlying object-based attention. We consider a broader biased-competition framework: task-irrelevant stimuli are suppressed according to how strongly they compete with task-relevant stimuli, with intensified competition when the irrelevant features or locations comprise the same object.

♦ **Evolving an identifiable face: the additive effect of combining techniques**

9   C Frowd[1], P Hancock[2], A McIntyre[2], C Brown[3], F Skelton[4], P Heard[5] ([1]University of Winchester; [2]University of Stirling; [3]University of Leeds; [4]University of Central Lancashire; [5]University of the West of England)

For about 15 years, we have been attempting to create a software system (EvoFIT) that produces an identifiable composite when constructed of an unfamiliar face after a long retention interval (as is the usual case in police investigations). EvoFIT has now been shown to be effective in police field trials and has been used in 20 police forces. More recently, some developments have been very effective on their own to improve composite quality—these include: (a) encouraging constructors to focus on the overall (global) properties of the face during the initial interview (Holistic CI, H-CI), (b) constructing internal features first (masking external features), and (c) presenting composites for naming using a perceptual image-stretch format. In the current project, we explored whether these techniques would produce even more identifiable composites when combined. Forty participants looked at a video of an unfamiliar target face and, 24 hours later, received an interview to obtain a description of the face (either CI/ H-CI) and then constructed a composite using EvoFIT (either blurry externals/internals-only). Further participants were presented with the resulting composites to name, first front-on (the usual way to view the face) and then by looking at the face sideways (perceptual stretch). The three techniques were effective independently, replicating past research, but together produced composites with an effect that was more than just additive—to yield a mean naming level of 74% correct. A composite system using all three of these techniques would therefore appear to be effective for police-work.

♦ **Binocular summation: what is the fate of monocular signals?**

10 M Georgeson[1], T Meese[1], D Baker[2], S Wallis[1] ([1]Aston University; [2]University of York)

Neural responses evoked by similar features in the left and right eyes are combined in primary visual cortex, and contrast sensitivity for two eyes is better than one. This binocular summation is the neural basis for binocular fusion and stereo vision. Here we ask whether the monocular signals ever have separate access to perception, without passing through the binocular-summing pathway. Most experiments are agnostic on this question, and most models have focussed on the summing mechanism(s). Our psychophysical experiments presented the same fixed-contrast, horizontal, 1 c/deg pedestal grating to both eyes, and in a 2AFC task observers had to detect changes (increment or decrement) in the pedestal contrast of one or both eyes. When the change takes place only in one eye, the binocular mechanism should be equally good at sensing an increment or decrement, but at higher pedestal contrasts (>5%) observers' performance was much worse for decrements than increments. Conversely, with an increment in one eye and a decrement in the other eye, the binocular mechanism should perform poorly (because the summed changes tend to cancel each other), but observers' thresholds were almost as good as for a one-eyed increment. These two critical results can be understood via three key principles: (i) signals from the two eyes are summed at low contrast but averaged at higher contrasts, (ii) monocular signals (L,R) are preserved in parallel with the combined one (B), and (iii) only the MAX over (L,R,B) is selected for further perceptual processing.

♦ **Metamerism? What metamerism?**

11 L D Griffin (University College London)

We consider a set of V1 simple cell like linear filters with similar spatial extents, applied to an image location, giving rise to a 'jet' of filter responses. Pairs of images can be vividly different even within the filters' extent yet give rise to identical jets. Such metameric pairs demonstrate that spatial vision fails uniquely to determine the image. This makes the proper interpretation of jets puzzling. How for example can a visual system assess whether the image exhibits a certain feature, for example a particular local symmetry, if the image is so under-determined? To resolve the puzzle we need to equip the jet space with an inner product structure, which makes explicit how we compare jets. This induces an effective inner product structure on the image space. We have shown that in certain cases this induced inner product is approximately the same as achieved by appropriately filtering the images, followed by windowing, and then comparing them using an ordinary dot product. For example, comparing the jets from a family of 1-D derivative-of-Gaussian filters from zero through to third order is the same as comparing the images that caused the jets using such a filter followed-by-windowing comparison scheme with an approximation error of only 0.2%. Hence we see that, while jets may fail uniquely to determine the image, they succeed in determining the image after a particular filtering and windowing operation with minimal ambiguity; and, since symmetry is invariant to filtering, jets are in fact perfect for assessing local image symmetry.

♦ **Looking at lips while speaking words masked with noise helps word recognition**
12 **and decreases the McGurk effect**

P Heard, A Ginis (University of the West of England)

It is well known that seeing lip movements helps word recognition. This study investigated this phenomenon using short unpredictable sentences (snippets). These were read out and the speaker's lips videoed (lips) and audio recorded. Snippets were made that had: (i) Lips and normal sound, (ii) Lips and sound with added low noise, (iii) Lips and sound with added high noise, (iv) Lips and no sound, (v) No lips and normal sound. The voice recognition was measured by syllables correctly identified. It was found that v) No lips and normal sound gave worse recognition than lips and normal sound so showing that lip reading helps word recognition. It was also found that lips with high noise gave better recognition than high noise with no lips or lips without any noise. McGurk stimuli where videos of lips are dubbed with a different sound such as lips Ga-Ga and audio Ba-Ba produces the perception of Da-Da. These were presented with high and low noise added to the sound. The McGurk perception reduced with the added noise and the perception corresponding to the lips increased.

♦ **Memory effects in bi-stable depth-order perception: Influence of active and passive**
13 **intermittent presentation of images**

L Hermans[1], D Stuer[1], R van Ee[1,2,3], J Wagemans[1], N Kogo[1] ([1]Laboratory of Experimental Psychology, University of Leuven, Leuven; [2]Donders Institute, Radboud University, Nijmegen; [3]Philips Research Laboratories, Eindhoven)

The assignment of the "owner side" of a border, is an important aspect in the computation of depth-order and figure-ground organization. There is evidence for the existence of border-ownership (BOWN) sensitive neurons in the lower visual cortex. A neural circuit of a feedback system has been suggested in which BOWN computation is influenced by depth-order, while depth-order is constructed from BOWN signals. We recently developed a neuro-computational model, which implemented this idea [Kogo et al., 2011, Vision Research, 51(18), 2085-2098]. This Differentiation Integration for Surface Completion (DISC) model reproduces bi-stable depth-order perception by adding noise and adaptation. The DISC model predicts that passive intermittent presentation of an image stabilizes the perception. This perceptual stabilization is also called prolongation effect and demonstrates the influence of recent history of visual experiences in bi-stable depth-order perception. Furthermore, it has been reported that an active intermittent presentation by opening and closing eyes caused an even stronger stabilization [Leopold et al., 2002, Nature Neuroscience, 5(6), 605-609]. In this study, we investigated the prolongation effect by a passive intermittent presentation using Kanizsa's anomalous transparency (KAT) image, Rubin's face or vase (FV) image and the Necker cube (NC). The prolongation effect was observed in KAT and NC, but not in FV. In addition, we investigated the prolongation effect when subjects saw the images intermittently by opening and closing their eyes. The prolongation is further enhanced, which suggests that a higher level expectation influences the perceptual organization when ambiguous images are presented.

♦ **Effects of orientation, speed and reference features on human direction perception**
14 A Hughes, D Tolhurst (University of Cambridge)

It has been shown that the orientation of stripes in a moving Gabor patch can bias direction judgements made by human observers in an occlusion paradigm (Hughes & Tolhurst, ECVP 2013). Here, we extend this finding to show that similar biases are observed in a different paradigm without occlusion. Observers viewed a Gabor target moving with a linear trajectory and were then asked to rotate a marker on the screen to indicate the direction they perceived the target to travel in. In the first experiment, observers showed marked biases in direction perception for all target types, but oblique stripes showed a different pattern of biases from targets with horizontal, vertical or no stripes. In the second experiment, we show that for target movement near the horizontal axis, patches with oblique stripes that pointed upwards relative to the direction of lateral motion were perceived to have a more upwards trajectory than patches where the stripes pointed downwards relative to the direction of motion. This is similar to previous findings using an occlusion paradigm. In a final experiment, we show that this bias becomes speed dependent when a reference feature is added to the display; the biases are similar to those shown in the previous experiment at high speeds, but reverse at low speeds. Our results suggest that human direction perception mechanisms are not truly veridical, and our judgements depend upon pattern orientation, speed and the presence of other features in the environment.

♦   A novel motion speed illusion reveals a new perceptual principle

15 D Huh (Gatsby Computational Neuroscience Unit, University College London)

The visual perception of biological motion has been suggested to have a tight coupling with the movement generation process. A well-known example is the speed illusion of single dot movements—the apparent fluctuation in the speed of a dot which is actually moving uniformly along a curved path. It has been suggested that the motion appears uniform only if it resembles the natural drawing motion of human subjects: For elliptic figures, this is known as the one-third power-law relationship between speed and curvature ($v(t) \sim r(t)^{1/3}$) (Viviani and Stucchi 1992). However, the phenomenon has not been rigorously studied for movements of general curve shapes. Our model based on optimality principle predicts a whole family of power-laws depending on the shape of movement paths, instead of the fixed 1/3 power-law. Such generalized relationship was indeed confirmed in our movement and perception experiments—smaller exponent is observed for a path shape whose curvature oscillates with higher frequency. The data, however, revealed different ranges of exponents for two tasks. In the motor task, the exponent ranged between 0 and 2/3, while it ranged between 0 and 1/2 in the perception task, which corresponds to two different conserved quantities predicted by our analysis. Therefore, our result reveals two similar yet different principles for perception and action processes of curved motion.

♦   Predicting image quality scores of linearly tone-mapped natural scenes

16 D Kane, M Bertalmio (Universitat Pompeu Fabra)

Tone mapping is the process of adjusting the luminance range of an image so that it fits within the limited range of a display device or print media. Linear scaling of images often produces images composed of dark, low contrast regions. This occurs because many natural images have a luminance distribution that is heavily concentrated towards the low luminance values. We investigate the perceived quality of natural images that have been linearly scaled to cover the full range of mean-luminance and contrast values that a CRT monitor can display. We find that image quality scores can be predicted by a three-stage model; First, luminance is passed through a compressive gamma function to compute 'perceived brightness'. Second contrast is computed as the standard deviation of the 'brightness' image. Third, an additional compressive gamma function is applied to the contrast scores. The model can predict image quality scores with a Pearson's correlation of R = 0.94 and is also able to predict the perceived quality of tone-mapped images in the database of Cadik et al. (2008) despite the existence of a wide variety of non-linear image artefacts (ringing, colour distortions, etc) in this image set (r = 0.83, p < 0.0001). We note that the two gamma functions shift their respective distributions towards the mid-values. An additional experiment reveals that the strength of the luminance gamma function varies inversely with the mean luminance of the image set suggesting the visual system is adaptively transforming the input distribution to allow for the optimal coding of natural scenes.

♦   On various ways of balancing colors

17 J Koenderink[1], A van Doorn[2], L Albertazzi[3], V Ekroll[1], J Wagemans[1] ([1]University of Leuven; [2]Utrecht University; [3]University of Trento)

 Two colors of different hue will stubbornly remain to look different, even when you change them in various ways–adjusting radiances, or adding achromatic beams. A conventional way of "balancing" two colors is to make them "equi-bright". This is heterochromatic photometry, generally considered a hairy topic. Why? Because equally bright colors still look different. There is no way to define equi-brightness, except operationally, but different operationalizations yield different results. Often thought of as problematic, it need not be if one indexes equi-brightness with the particular operationalization. Here we compare three particular methods. One is "motion nulling", which might be considered the conventional method of choice. It derives from flicker photometry, and yields results that approximate the CIE definitions, which makes one feel at home. However, this type of photometry addresses an essentially color-blind visual subsystem that is hardly involved in matters of static presentations, especially those in which hue plays a role. We studied two alternative methods that seem especially opportune in studies of static, Gestalt-like visual awareness. We find such methods to yield a balancing of colors of different hue that is very different from the conventional method. We mention "balanced" instead of "equi-bright" because of such differences. These methods are to be preferred in frequent cases, where the conventional "brightness", or the CIE definitions are of rather limited applicability.

♦ **Border-ownership computation with consistency detection of surface properties**
18 N Kogo[1], V Froyen[2] ([1]University of Leuven; [2]Rutgers University)
When an image is segmented, humans often perceive convex regions as figures. However, in certain conditions, this convexity preference is reduced. For example, if a convex region is in the middle of another surface and has the same color/texture as the background, it is often perceived as a hole. The preference of convex regions in repetitive columnar configurations is also reduced if the concave regions have inconsistent colors (Peterson & Salvagio, 2008, Journal of Vision, 8(16):4, 1–13). These data suggest that consistency of surface properties plays a key role in figure-ground organization. Importantly, Zhou et al. (2000, Journal of Neuroscience, 20(17), 6594–6611) showed that about 70% of border-ownership (BOWN) sensitive neurons in V2/V4 were also sensitive to contrast polarity. Accordingly, Zhaoping (2005, Neuron, 47(1), 143–153) developed a model in which BOWN signals are enhanced when they are consistent in both the ownership and the contrast polarity. Inspired by her model, we first developed a simplified algorithm to compute BOWN to model illusory contour perception (DISC model, Kogo et al, 2010, Psychological Review, 117(2), 406–439). We recently tested the performance of the model which also reflects the consistency of the surface colors at the location of the signals as in Zhaoping's model. We report that this approach gives extremely robust responses to various images with complexities both in shapes and in depth orders such as the examples mentioned above, suggesting the importance of this approach for BOWN computation as first proposed by Zhaoping (2005).

♦ **Psychopy_ext: A framework for streamlining research workflow in neuroscience**
19 **and psychology**
      J Kubilius (KU Leuven)
Successful accumulation of knowledge is critically dependent on the ability to verify and replicate every part of a scientific conduct. However, such principles are difficult to enact when researchers continue to resort on ad hoc workflows resulting in a poorly maintained code base. Based on a critical examination of the needs of neuroscience and psychology community, I introduce psychopy_ext, a unifying framework that seamlessly integrates experiment building, analysis and manuscript preparation by choosing reasonable defaults and implementing relatively rigid patterns of workflow. This structure allows automation of multiple tasks, such as automatic user interfaces, unit testing, stimulus control analyses, single-command access to descriptive statistics, and publication quality plotting. Taken together, psychopy_ext opens an exciting possibility for faster, more robust code development and collaboration for researchers.

♦ **Towards a generic model for figure-ground segmentation**
20 J Kubilius, J Wagemans, H Op d e Beeck (KU Leuven)
While multiple studies investigate the properties of the earliest and final stages of visual information processing, the underlying transformations leading from simple edge detection to object recognition remain seemingly intractable. To tackle this problem, we take a step back and ask what mechanisms could lead to a successful figure-ground segmentation of a given image. We propose the following conceptual framework: (i) alternating steps of feature detection and feature pooling (grouping) in a hierarchical manner; (ii) segmentation into (provisional) objects by an unsupervised learning procedure using the computed feature grouping strengths. We present an initial implementation of this model where grouping principles such as proximity or good continuation are leveraged to discover grouped objects in an image. Model simulations reveal a promising performance on classical Gestalt displays of dot lattices, contour integration, and texture segregation.

♦ **Saccades are not affected by the infinite regress illusion**
21 M Lisi, P Cavanagh (Laboratoire Psychologie de la Perception (CNRS 8158), Université Paris Descartes)
One of the primary functions of the visual system is to localize objects in the environment. The computation of an object's location takes into account more than simply its locus of retinal stimulation, as it has been shown by many psychophysical studies where visual motion influences the perceived location of stationary stimuli. A classical result is that a stationary aperture filled with a drifting sinusoidal grating appear to be displaced in the direction of motion (De Valois & De Valois, 1991). This illusion seems to also affect the visuomotor system, as saccades to static, drifting Gabor patches show offsets in the saccade landing positions coherent with the offsets in perceived position (Kosovicheva, Wolfe, & Whitney, 2012). In the present study we presented stimuli with both motion within the aperture and

motion of the aperture itself, with the direction of one motion vector orthogonal to the other one based on the infinite regress illusion of Tse and Hsieh. This combination leads to a striking illusion, in which the perceived direction of the aperture is given by the sum of the two orthogonal motion vectors (Tse & Hsieh, 2006), and the perceived location of the aperture itself can be shifted up to several times its size away from its physical location. We measured both the perceptual and saccadic localization of brief flashes superimposed on the motion stimuli, and, surprisingly, we found that saccades did not show the perceptual position shifts, but instead appeared to target the physical locations of the flashes. A tentative interpretation of the data is provided, in terms of temporal integration of position and motion signals that happens over different timescales for saccadic and perceptual decisions.

♦ **The effect of depth cues in a 2D motion pattern on vection and postural sway**

22 A J A Lubeck[1], J E Bos[2], J F Stins[1] ([1]Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam; [2]TNO Perceptual and Cognitive Systems, Soesterberg)

Vection (the illusion of visually induced self motion) can be more powerful when a stationary scene or object is placed in front of a moving pattern, and weakened when placed behind the pattern. In addition to the sensation of vection, these moving patterns also influence postural sway. In earlier research a real stationary object was placed in front of or behind the motion pattern. In this experiment we studied whether addition of a virtual object to a virtual 2D pattern rotating in roll (ie, in the frontal plane) can yield the same effects on vection and postural sway as placing a real object in front of a motion pattern. The pattern was presented either (a) without an object, (b) with an object behind the pattern, (c) in the same plane or (d) in front of the pattern. During exposure postural sway was recorded using a force plate, and vection was reported using a 3-point scale (no, sometimes, continuously). Results showed that postural sway and vection scores were only affected by rotation of the pattern and not by the placement of the object. Vection scores also appeared to be higher for larger postural sway. Thus, a 2D rotating pattern increases vection and postural sway. However, creating a depth structure by adding a virtual object did not seem to influence vection or postural sway. We did find vection scores and postural sway to be correlated, and therefore postural sway may be an objective measure to quantify vection.

♦ **How do we update mental simulations at the right speed?**

23 A Makin, M Bertamini (University of Liverpool)

People live in a dynamic environment. Fortunately, we can update our mental representations whenever the world changes. Interestingly, people can also update mental representations without sensory input, and we can do this at an appropriate rate. In this work, we explored the brain's rate control systems. One hypothesis is that a common rate controller guides all dynamic updating. An alternative is that separate rate controllers guide updating in different modalities and dimensions. We compared performance on two updating tasks. In the Position extrapolation task, participants viewed a target moving along a track, then disappear at an unpredictable point. They had to press a button when it reached the end of the track. In the Accumulation extrapolation task, participants view an empty space filling with gabors. The accumulation process paused before completion, but participants assumed ongoing, hidden accumulation, then pressed when the process was complete. The Position and Accumulation tasks were interleaved, and temporal parameters were matched. We found evidence that a common rate controller guided performance on both: First, task parameters influence response time in a similar way, and second, performance was correlated, so participants who pressed early on one task tended to do so on the other. Further experiments replicated this with different kinds of dynamic stimuli, such as change in number space. We conclude that a common rate controller may guide all forms of mental updating.

♦ **Perception of global image contrast: integration and suppression of local contrasts,**

24 not MAX or RMS

T Meese[1], D Baker[2], R Summers[1] ([1]Aston University; [2]University of York)

When we adjust the contrast knob on a TV set, we experience a perceptual change in global image contrast. Here we ask how that image statistic is computed. We used a contrast-matching task for checkerboard configurations of micro-patterns (known as Battenbergs), where A- and B-contrasts refer to the Michelson contrasts of 2D arrays of micro-patterns placed on the nominal 'black' and 'white' regions of the checkerboard, respectively. Mean luminance of the micro-patterns was the same as the mid-grey background. With this arrangement we could manipulate the A-contrasts (0–32%) independently of the B-contrasts, which were always set to 8% in the standard stimulus. Using a

staircase procedure, the adjustable matching patterns had A- and B-contrasts that were either equal (full-match), or one of them was 0% (half-match). Stimuli were 20×20 arrays with check widths of either: 1, 2, 4, or 8 micro-patterns. At the extreme A-contrasts, perception depended on the highest contrast in the image. But for all four check-widths and both match types, there was a curious intermediate region where adding low A-contrast to B-contrast caused a paradoxical reduction in perceived global contrast. None of the following models predicted this: RMS, energy, linear sum, max, Legge & Foley. However, a gain control model incorporating wide-field integration and suppression of nonlinear contrast responses predicted the results with no free parameters. This model also accounts for summation of contrast at threshold, and challenging masking and summation effects in dipper functions. Thus, we conclude it represents a fundamental operation in human contrast vision.

♦ **Can one predict which direction comes next during tri-stable motion perception?**
25 A I Meso[1], J Rankin[2], P Kornprobst[2], G S Masson[1] ([1]CNRS/Aix-Marseille Université; [2]INRIA)
We study competition between perceptual states empirically and theoretically with ambiguous moving stimuli to better understand what governs transition sequences. An obliquely moving grating presented behind a square aperture (a barber-pole) is tri-stable. Horizontal (H), diagonal (D) and vertical (V) perceived directions are intermittently possible. Over 15 s presentations, observers indicate the time of each perceptual switch between H, D and V while eye movements are recorded. When transitions are categorised ie away from D (1), towards D (2), and between H-V (3), class (3) rises in proportion as contrast increases from 0.03 to 0.2 and the rest conversely decrease. This is explained by our neural fields model of multi-stable motion integration in which the three states have different characteristic stability terms, τ for D (the Eigen value for this state) and f (the H-V Floquet exponent) for the cardinals. These terms characterise the decay constants of the states which we show to depend on contrast. Eye movements confirm that the percept is typically initiated in the vector-average direction D, whose duration is governed by τ before transition 1. What happens next is contrast dependent; (2) and (3) are in competition. As f becomes more negative at higher contrasts, making cardinals more stable, 3 dominates. The implication is that the elapsed time from onset interacts with the contrast which determines τ and f, thus constrains the possible transitions for this stimulus. We can therefore estimate the probability of the different transitions as a function of contrast which evolves in time.

♦ **Comparing the effects of action and casual video game play on central and peripheral**
26 **contrast sensitivity**
      A Mikailionyte, J Lauritzen (Kingston University)
The effect of action gaming on vision has been studied extensively (Green and Bavelier, 2012, Curr Biol, 22(6), 197–206), but there have been few studies into casual gaming (Consalvo, 2009, Proc 4th Intl Conf on Foundations of Digital Games, 50–54.). This study compares measures of visual function in action (AVGP), casual (CVGP) and non-gamers (NVGP). 27 participants with an average age of 23 participated in psychophysical experiments programmed using the Psychophysics Toolbox extensions for MATLAB (Brainard, 1997, Spat Vis, 10, 433–436). Participants' gaming habits were evaluated using a short questionnaire. Spatial contrast sensitivity (CS), temporal CS for 20 Hz and 24 Hz, and peripheral spatial and temporal CS were assessed at four spatial frequencies. CVGPs had lower CS compared to AVGPs for temporal and peripheral contrast sensitivity, but higher CS than NVGPs. There was no significant difference between the 3 groups' foveal spatial contrast sensitivity. Specifically, AVGS are significantly ($p < 0.05$, two-way rmANOVA, df = 2, 24) more sensitive than CVGs and NVGs at the temporal frequency of 24 Hz and for all peripheral CS measures while CVGs are significantly more sensitive than NVGs at temporal frequency of 20 Hz and peripheral temporal CS. This may be attributed to the varying attentional capacities required for the two different game genres and the psychophysical tasks studied, respectively (Green and Bavelier, 2006, J Exp Psychol Hum Percept Perform, 32(6), 1465–1478).

♦ **Reclaiming the periphery: Automated kinetic perimetry in patients with glaucoma**
27 **and healthy controls**
      V M Moenter[1], D P Crabb[1], P H Artes[2] ([1]Department of Optometry and Visual Science, City
      University London; [2]Ophthalmology and Visual Sciences, Dalhousie University & Capital Health,
      Halifax)
Visual field (VF) tests used in clinics typically focus on a central area that neglects more than 80% of a person's overall VF. We are aiming to develop a fully automated VF test for the entire VF combining static and kinetic perimetry. To combine static and kinetic measurements, we need to understand their

properties when measured in the peripheral VF. In this pilot work VFs of 8 patients with glaucoma and 11 people with healthy vision were examined with an Octopus 900 (Haag-Streit AG, Koeniz, Switzerland). Kinetic stimuli (Goldmann III1e, 0.43°, 15 dB, speed 5°/sec) were presented along 16 meridians. The median response to three presentations defined an isopter. Frequency-of-seeing data were then obtained to static stimuli (duration: 200 ms), at five visual field locations on the kinetic isopter (10 presentation of 8 intensities). Psychometric functions were fitted with a Probit model as well as with a non-parametric approach. Sensitivity to static stimuli is lower than sensitivity to kinetic stimuli by on average 3.3 dB [95% confidence interval: 2.9 to 3.7 dB], which is in line with previous findings (Hudson et al, 1992, IOVS, 33, 3162–3168). Response variability at peripheral locations is lower than expected for locations of the same sensitivity in the central VF (Henson et al, 2000, IOVS, 41, 417–421). These preliminary results suggest that the relationship between sensitivity and response variability is not uniform throughout the VF and sensitivity measurements are more reliable in the periphery than expected.

♦ **What causes the Kanizsa stimulus to break interocular suppression?**
28 P Moors, S van Crombruggen, J Wagemans, R van Ee, L de-Wit (University of Leuven)
A regular, grouped Kanizsa triangle has been shown to break through interocular suppression faster than an ungrouped, random Kanizsa triangle [Wang et al., 2012, PLoS ONE, 7(6): e40106]. In an earlier neuropsychological study Conci et al. [2009, Neuropsychologia, 47, 726–732] showed that low-level collinear contour facilitation and high-level surface filling-in both contribute separately to a reduction in extinction in patients with visual neglect when viewing Kanizsa stimuli. Since Wang et al. (2012) did not include control conditions similar to Conci et al. (2009), it is not clear whether the Kanizsa triangle broke through suppression due to collinear contour facilitation or higher-level surface completion mechanisms [Kogo et al., 2010, Psychological Review, 117(2), 406–439]. In this study, we compared suppression times of regular and random versions of a Kanizsa square, a cross stimulus (allowing collinear contour facilitation but no surface completion) and a surface stimulus (allowing surface completion but no collinear contour facilitation). Our results suggest that neither collinear contour facilitation nor surface completion mechanisms play a primary role in determining suppression times. Rather, the regularity of the stimulus seems to play a crucial role. This hypothesis was tested further by breaking down the regularity of the different classes of stimuli.

♦ **Scene descriptions at multiple spatial scales**
29 C Mullin[1], N Van Rijsbergen[2], P Schyns[2], J Wagemans[1] ([1]Laboratory of Experimental Psychology, KU Leuven; [2]Institute of Neuroscience and Psychology, University of Glasgow)
Scenes contain a wealth of information that can be selected and processed differently depending on the requirements of the observer. While some scenes are categorized by their global spatial layout (eg corridor), others are defined by local diagnostic objects (eg bed in a bedroom). As such, certain scenes are defined more by their boundary related parts while others are defined more by their content related parts. Additionally, the scale of information required to identify and categorize a scene changes depending on the level of classification (subordinate, basic, superordinate). Several studies that have attempted to characterize scenes based on hierarchy of components and spatial scale often cue the participant to respond to one of these specific levels. These task demands may potentially bias the perception of the scene overall. As a result, it is difficult to draw strong conclusions regarding the way scenes are processed and perceived. We conducted an extensive, systematic investigation using an uncued task, in which participants freely described scenes at multiple spatial scales. Independent observers subsequently rated the responses for accuracy on a predetermined list of attributes, shown to tap into hierarchical categorization. Our results reveal which objects are characterizable on multiple spatial scales, and which are localized to specific scales. Results are discussed with reference to new ways of describing local and global aspects of scene processing.

♦ **Eyes on emergence**
30 B Nordhjem[1], C I Kurman Petrozzelli[1], N Gravel[1], R Renken[2], F W Cornelissen[1] ([1]Laboratory of Experimental Ophthalmology, University Medical Center Groningen, University of Groningen; [2]Neuro Imaging Center, University Medical Center Groningen, University of Groningen)
It is often said that the sum is more than its parts. This is the underlying concept of emergence where individual components give rise to the percept of a whole figure. We here investigated how eye movements are distributed during the recognition of images with emerging properties. Emerging images resembling the Dalmatian against a dappled background were created based on the computer

algorithm by Mitra, Chu, Lee, and Wolf (2009). Although emerging images initially appear as abstract patterns, the embedded object can usually be recognized after a while. Viewing patterns were recorded with eye tracking, and observers indicated the moment of object recognition with a key press. The distances between fixations and the edges of the embedded object were calculated over time. Approx. 1 s before recognition, there was a clear shift from scanning the whole stimuli to fixations on the edges of the object. Three stages immediately before recognition were identified; fixations just outside the object, fixations inside the object and finally, fixations right on the edges. After recognition, fixations again became more distributed. Our findings show that emerging images may be used to identify sub-stages in the recognition of objects by revealing the presence of systematic tendencies in the fixation patterns that observers make. Such information may be used to enhance existing models of dynamic perception. In future research, we intend to investigate the link between eye-movements and the underlying neural mechanisms with emerging images.

♦ **Visual complexity and perceived duration**

31   L Palumbo[1], R Ogden[2], A Makin[1], M Bertamini[1] ([1]University of Liverpool; [2]John Moores University)

In two studies we investigated whether visual complexity of novel abstract-block patterns affects perceived duration. Previous research reported that complex visual stimuli lead to an underestimation of durations. However, due to the nature of the stimuli it is unclear which component of image complexity, spatial or semantic, played the critical role. Here we tested the impact of specific spatial properties of complexity on perceived durations. We used a black and white checkerboard and the difference between stimuli was only in configuration. Visual complexity was quantified by an index based on GIF compression. We found that GIF indexes correlated positively to subjective perceived complexity (r = 0.64) (Experiment 1a). Observers estimated pattern durations in seconds using a continuous scale. A multilevel linear analysis reported that estimated duration was not predicted by visual complexity (Experiment 1b). In the second study we increased variability in the stimuli by changing the number of items across patterns (numerosity parameter) while keeping overall size constant. Higher positive correlations were found between objective rates and subjective evaluations of complexity (r = 0.95) (Experiment 2a). We confirmed with the new set of stimuli that when visual complexity is defined at the configuration level it does not influence perceived durations. The results are discussed in relation to theories of time perception hypothesizing that complexity leads to an underestimation of duration when it indirectly reduces attention to time. Additionally, the current debate on the use of computer-based measures of visual complexity is discussed.

♦ **Peripheral contrast sensitivity is impaired in adults with reading difficulties**

32   S Panchagnula, A Augousti, D McGlade, B Pierscionek, J Lauritzen (Kingston University)

We present evidence of a low-level deficit in peripheral contrast sensitivity (CS) of adults with reading difficulties (RD) that may impair gaze control. This could explain defects in directing attention (Bosse et al., 2007, Cognition, 104(2), 198-230) and temporal processing (Laycock et al., 2012, Neuropsychologia, 50(8), 2101–2113). 21 adult volunteer participants (aged 20–49) were recruited. Seven were classified as having RD. Subjective reading experience of participants was evaluated using a vision questionnaire. Reading speed and traits were measured using a specially designed test (Griffith, personal communication). Assessments of visual acuity, stereoacuity, tests for colour anomalies, manual perimetry and standard binocular vision tests were carried out. Stimuli were programmed using the psychophysics toolbox for MATLAB (Brainard, 1997, Spat Vis, 10, 433–436), and displayed on a 120 Hz LCD display. Central and 10° peripheral, spatial and temporal CS of participants were assessed using Gabor patches at spatial frequencies of 0.3, 1 and 3 cycles per degree. Stimuli were presented binocularly for 500 ms. Luminance and isoluminant colour CS were determined. These were measured using a 2-AFC paradigm along a 3-down-1-up staircase. Thresholds were calculated as the mean of the last three of five reversals. Participants with RD had significantly (ANOVA: $p < 0.05$, df = 1, 19) lower peripheral CS for all conditions tested, and significantly lower central CS for the blue-yellow isoluminant stimulus, compared with controls. Lower CS in the peripheral retina may impair accurate control of gaze position and eye movements, and thus impede reading rate.

♦   **Main axis of elongation dynamics and the planar bias in active object inspection:**
33 A developmental approach

A Pereira[1], I Lisboa[1], E Sousa[1], J Santos[1], K James[2], S Jones[2], L Smith[2] ([1]University of Minho; [2]Indiana University Bloomington)

As we turn our bodies, as we hold and move objects close to us and act on them, we generate dynamic views. Recent studies have examined the viewpoints that infants select during free play and found large developmental changes in dwell time distribution, namely an increasing preference for orienting objects on or around planar views—ie main axis is parallel (foreshortened) or perpendicular to the line of sight, and flat surfaces are perpendicular. This bias is characteristic of mature viewing and was found to promote more efficient learning. The functional role of this bias is poorly understood. We investigated two properties that seem relevant: (1) main axis expansion/foreshortening, and (2) instability—related to dynamic viewing, where rotations around planar views typically yield larger visual changes. In two experiments (E1: N = 21, 18–24 months; E2: N = 54, 12–36 months), children inspected objects in a free play task and we measured 3D orientation; the main measures were the angle between the main axis of elongation and the line of sight, and its angular velocity and acceleration. There were two key results: (1) main axis is typically maintained in view (infrequent foreshortening)—this suggests that elongation is a distinctive property of preferred views; (2) planar views correspond to more stable periods of the object manipulation—this suggests that sampling planar views corresponds to moments of focused attention to a particular view and perhaps learning of a static view is occurring, leaving open the question of how view transitions are integrated over time.

♦   **Selectivity of face perception to horizontal information over lifespan (from 6 to 74 year old)**
34   A Poncin[1], C Schiltz[2], V Goffaux[1] ([1]UC Louvain; [2]University of Luxembourg)

Face recognition in young human adults preferentially relies on the processing of horizontally-oriented visual information. The present study addressed whether tuning to horizontal information is modulated by the extensive experience that humans acquire with faces over the lifespan, or whether it reflects an invariable prewired processing bias for this visual category. We tested 282 subjects aged from 6 to 74 years in a face matching task designed to achieve above chance-level performance across ages. Stimuli were upright and inverted faces filtered to preserve information in the horizontal (H), vertical (V) or both (HV) orientation ranges. The engagement of face-specific processing was inferred by comparing matching performance with upright and inverted faces (ie, face inversion effect, FIE). The FIE was significant in HV and H conditions only, replicating previous evidence that face-specific processing is selectively related to horizontal information handling. Overall, the magnitude of the FIE significantly increased from 6 to 18 years, corroborating the view that face-specific processing is a late-maturing process. We also found that the FIE-size in HV and H correlated with age as the RT difference between upright and inverted conditions tended to increase linearly as a function of age. In contrast, the FIE-size in V condition was not modulated by age. Processing of horizontal facial information (in HV and H stimuli) thus systematically showed the largest developmental changes. These findings indicate that face-specific processing is modulated by the extensive experience humans acquire at extracting the visual cues located in the horizontal orientation band of upright faces.

♦   **An absolute interval scale for approximate order of 2D point patterns**
35   E Protonotarios, A Johnston, L D Griffin (University College London)

The degree to which a point pattern is approximately ordered seems to be a dimension of its appearance. Based on analysis of data from twenty subjects, who each ranked by approximate order all pairs from a set of twenty patterns, we have established that the dimension is highly consistent between individuals and has an interval scale structure spanning roughly 10 just-noticeable-differences (jnds) between perfect disorder and order. We have developed a geometric algorithm that estimates the approximate order of patterns to an accuracy of 0.5 jnd. The algorithm works by assessing the variability of the spaces between points as expressed in their Delaunay Triangulation. Specifically it sums the entropies of the univariate distribution of triangle sizes and the bivariate distribution of triangle shapes. Our algorithm is three times more accurate than the variance of the number of nearest neighbours which is the best amongst measures previously proposed. We have anchored the output of the algorithm so that Poisson point processes score on average 0, perfect lattices score 10, and unit steps correspond closely to jnds. The resulting absolute, interval scale is useful in Biology where the development of tissue towards order is an example, amongst many, where quantification of order would be desirable. Our scale, as defined by our algorithm, quantifies order with an

agreement to the consensus as accurate as a committee of seven raters, while being fully objective and repeatable. Its scope is limited to point patterns that do not present multiple levels of organization. [Supported by EPSRC, IKY.]

♦ **I will write I Love You on … a symmetrical pattern!! An ERP evidence of affective**
36 congruency between pattern regularity and word valence
   G Rampone, A Makin, M Bertamini (University of Liverpool)

The intimate connection between symmetry and beauty is well established. People explicitly like more symmetrical than random abstract patterns. Moreover, they associate symmetry with positive valence and random with negative valence on implicit behavioural tasks. The aim of this study was to investigate the neural correlate of this association (the congruency effect). We presented reflection and random patterns with either a positive or a negative word superimposed and recorded ERPs from posterior electrode clusters. Experiment 1 was divided in two tasks: in Discriminate Regularity task participants classified the regularity of the pattern (reflection or random). In Discriminate Valence task they reported the valence of the word (negative or positive). Experiment 2 required simultaneous discrimination of regularity and valence on each trial. ERP analysis evidenced a congruency effect between symmetry and positive words starting from 200 ms up to 1000 ms after stimulus onset. Interestingly, this effect was visible only in the Discriminate Word task. Possibly word valence is easier and faster to evaluate and participants automatically evaluate the valence of the pattern on the background, which in turn alters early visual processing.

♦ **A convexity bias in the processing of motion parallax transformations**
37 B Rogers[1], H Hill[2] ([1]University of Oxford; [2]University of Wollongong)

Concave face masks are typically seen as convex even when viewed binocularly where there is concave disparity information. This bias has been attributed to the overwhelming prevalence of normal convex faces in our previous experience (Gregory, The Intelligent Eye, 1970) or to a general convexity preference reflecting the statistical dominance of convex forms in the natural environment (Hill and Johnston, Perception, 36, 1992). Georgeson (Perception, 8, 1979) reported that this bias can be overcome if a concave face mask is covered with random dots to increase the disparity information specifying concavity. We have replicated this result using a 'virtual hollow face' technique (Rogers, JOV, 10, 2010) in which we independently manipulated (i) shading information, (ii) disparity information and (iii) motion parallax information during side-to-side head movements. We also manipulated the relative contrast of the shading information on the face and a superimposed random dot pattern. At the point where a stationary observer first reported that the mask appeared concave (due to the increased contrast of the disparities), we found that the mask 'flipped' back to appearing convex when the observer started moving from side-to-side. This reveals that there is a strong bias towards convexity in the processing of motion parallax transformations. A similar result was found with unfamiliar 3D forms, suggesting that the effect is not specific to faces. In addition, these results confirm our previous finding that the visual system shows little or no preference for seeing motion parallax-specified objects as stationary during observer movement (Rogers, JOV, 12, 2012).

♦ **Drawings reveal what is lost in crowding**
38 B Sayim, J Wagemans (KU Leuven)

Objects in peripheral vision that can be identified in isolation are often not discernible when flanked by similar close-by objects, a phenomenon known as crowding. We investigated crowding by letting observers draw stimuli presented in the visual periphery. Targets consisted of a letter, a letter-like item, or a scrambled letter and were presented with or without flankers of different complexity. Targets were presented in the right visual field at eccentricities of 6 or 12 degrees. Observers were asked to draw how the stimuli appeared to them as accurately as possible. Eye tracking ensured that stimuli were only presented when observers fixated on a central fixation dot. The drawings were rated on scales capturing the differences between presented stimuli and resulting drawings. We found evidence for strong appearance changes when the stimuli were crowded. The most common difference between stimuli and drawings was that elements were missing in the drawings. Other errors included position shifts, distortions, and adding of elements. Our results show that information loss is a key feature of crowding. Drawings are a useful tool to capture "perceptual errors" that are not observed in standard crowding paradigms.

♦ **Imagining circles**

39 G Schmidtmann, F A A Kingdom (McGill University, Department of Ophthalmology, Vision Research)

Previous studies have shown that the visual system is specialized for circular shapes. We investigated the accuracy for interpolating a circle and judging its centre-point from circular segments of varying angular extents (AE: 22.5°–270°) and radii (1°, 2° & 3°). Experiment 1: Subjects (N = 4) were asked to position a centre-point when presented with a vertically presented arc of varying AE. Experiment 2: Subjects were asked to align two opposing arcs to form a circle. Experiment 3: Subjects were presented with two opposite arcs of a circle and asked to position a dot between them to form a circle. Results Exp. 1: Centre-points are positioned further from actual centre-points for all radii tested. The bias decreases with increasing AE, reaching accurate estimates for AEs beyond 135°. The arc-size illusion (ASI), in which short arcs are perceived flatter than same-radius longer arcs may account for the initial overestimation. However, Exps. 2 & 3 showed the opposite result: an underestimation of (a) the distance between arcs (Exp. 2) and (b) the distance of the dot from the centre (Exp. 3). This bias decreases linearly for arcs up to 90°, and increases with radius. The underestimation might be caused by subjects judging the arc segments as sides of an interpolated quadrilateral shape, and is in agreement with the principle of good continuation, formalized as the minimization of both curvature and length.

♦ **Sensitivity to non-accidental configurations of two-line stimuli**

40 C Sleurs, J Kubilius, H Op de Beeck, J Wagemans (KU Leuven)

According to recognition-by-components theory, object recognition relies on a specific subset of three-dimensional shapes called geons. In particular, these configurations are a powerful cue to a three dimensional object reconstruction because their two dimensional projection remains viewpoint-invariant. While a large body of literature has demonstrated sensitivity to changes in these so-called non-accidental configurations, it remains unclear what information is used in establishing such sensitivity. In this study, we explored a possibility that non-accidental configurations can already be inferred from the basic constituents of objects, namely, their edges. We constructed a set of stimuli composed of two lines corresponding to various non-accidental properties and configuration of geons, including collinearity, alignment, curvature of contours, curvature of configuration axis, expansion, cotermination, and junction type. Using a simple visual search paradigm, we demonstrated that participants were faster at detecting targets that differed from distractors in a non-accidental configuration than in a metric one. Given that such sensitivity emerged from a configuration of only two lines, our results open a possibility that non-accidental configurations could be encoded at the earliest stages of the visual information processing.

♦ **Chromatic adaptation to coloured light sources**

41 K A G Smet[1], G Deconinck[2], P Hanselaer[1] ([1]Light and Lighting Laboratory–ESAT KU Leuven; [2]ESAT-ELECTA KU Leuven)

Chromatic adaptation refers to the ability of the human visual system to (partially) adapt to the intensity and colour of the illumination, producing an approximately colour constant appearance of objects across changes in illumination. It has been studied intensively during the past decades for its scientific potential to improve our understanding of human colour vision and for its practical implications in lighting design, printing and display technology. Models that predict the adaptive shift due to changes in lighting/viewing conditions are referred to as Chromatic Adaptation Transforms (CATs). They are typically based on one or more sets of corresponding colours (CC), which are colours that appear similar under different lighting conditions. However, most previous CC experiments were limited to near neutral illuminants, while new solid-state lighting technologies open up a range of potentially chromatic illuminants for which no systematic CCs or CAT is available. Therefore, new CC data will be collected to (1) increase our understanding of CA and (2) to derive a new CAT applicable to a wider range of illuminants. CC data will be collected using a novel viewing booth in which a data projector will be used to independently adjust the chromaticity and luminance of a real 3D stimulus and of the background adaptation field. The projector based setup allows a strict focus on the adaptive shift by seperating it from the colorimetric illuminant shift, while the enhanced realism of physical 3D scenes, compared to 2D stimuli presented on a display, should result in a chromatic adaptation process more representative of real-life viewing conditions (eg it has been reported that the degree of adaptation is lower for softcopy stimuli).

♦   **Visual search speed is driven primarily by visual similarity of objects in peripheral,**
42   not foveal vision
R Southwell[1], A Hughes[1], D Tolhurst[1], I Gilchrist[2] ([1]University of Cambridge; [2]University of Bristol)
We performed rating and search experiments to clarify a seminal theory of visual search. Duncan and Humphreys (1989, Psych. Review 96(3):433–458) identified three factors affecting search for a target amongst distractors: (i) the similarity of the target to the distractors, (ii) the similarity of the distractors to one another and (iii) the number of distractors. However it is not clear whether the 'similarity' terms pertain to comparisons made in foveal or peripheral vision. Given the importance of peripheral vision in guiding eye movements about a search scene, we hypothesise that peripheral visibility of elements is an important factor in determining search times. We performed a ratings task to quantify the perceived differences between pairs of naturalistic image patches, foveally and at several eccentricities. Some image pairs were found to be 'metameric', appearing similar in peripheral vision but clearly different when compared foveally. Search scenes were formed using target and distractor elements, where the similarity between elements was known from the ratings experiment for both foveal and peripheral comparisons. Some scenes had metameric elements; others had elements that were as easy to distinguish peripherally as foveally. Search scenes where the target was peripherally metameric with the distractors were difficult, as measured by long search times, despite the large difference between target and distractors as viewed foveally. Stepwise multilinear regression confirmed that peripheral ratings rather than foveal ratings were the better predictors of search speed, confirming that the information from peripheral vision is critical in guiding decisions and eye movements during search.

♦   **Shape aftereffects are more than meets the eye**
43   K Storrs[1], D Arnold[2] ([1]University College London; [2]University of Queensland)
One of the earliest reported visual aftereffects is the shape aftereffect, wherein looking at a particular shape can make subsequent shapes seem distorted in the "opposite" direction. After viewing a narrow ellipse, for example, a perfect circle can look like a broad ellipse. However, perceived shape is invariant for large changes in the retinal image resulting from different viewing angles, raising the previously untested question of whether shape aftereffects are determined by the dimensions of retinal shapes or perceived shapes. By viewing adaptors from an angle, with subsequent fronto-parallel tests, we establish that shape aftereffects are not solely determined by the dimensions of successive retinal images. Moreover, by comparing adaptation to the same retinal shape with and without stereo surface-slant cues, we show that shape aftereffects reflect a weighted function of retinal image shape and surface slant information, a hallmark of shape constancy operations. Thus our data establish that shape aftereffects can be influenced by perceived shape, as determined by constancy operations, and therefore likely involve higher-level neural substrates than previously thought.

♦   **Does action disrupt multiple object tracking?**
44   I M Thornton[1], T S Horowitz[2], H H Bülthoff[3] ([1]University of Malta; [2]National Cancer Institute, United States; [3]Max-Planck Institute)
Multiple Object Tracking (MOT) has proven to be a very useful laboratory tool for exploring the limits of divided attention. Compared to many other attention tasks, MOT appears to capture much of the complexity of our day-to-day environment. Often though, for example when driving or playing sport, we need to act on the environment as well as simply monitor it. In the current work, we asked whether the need to make focused, task-relevant movements, would interfere with the ability to track multiple objects. Sixteen participants completed single-task versions of standard MOT and a new collision-avoidance task that we call interactive multiple object tracking (iMOT). In the iMOT task, which is based on the popular mobile app games Flight Controller and Harbor Master, the goal is to stop objects colliding by using touch control to perturb trajectories. Compared to single-task baseline, iMOT performance decreased and MOT performance increased when the two tasks had to be performed together. Although strategic allocation of resources may partly account for this pattern of cost and benefits, it seems clear that actions can be planned and executed at the same time as tracking multiple objects.

♦ **Uncertainty in ratings for perceived differences in naturalistic image stimuli in peripheral**
45 vision
D Tolhurst[1], A Hughes[1], O Meacock[1], I Gilchrist[2], R Southwell[1] ([1]University of Cambridge; [2]School of Psychology, University of Bristol)
To et al (2011, Vision Research, 51, 1686) reported experiments comparing foveal with peripheral vision where observers gave numerical ratings of how much difference they perceived between successively presented natural image patches, which differed chromatically or spatially. Subsequently, we have noticed a phenomenon that is retrospectively discernible in our original published graphs. We instruct observers to give a rating of zero if they perceive no difference between paired images. We include trials where the paired images are actually identical; observers are told this, and we expect them to give ratings of zero to such pairs. Foveally, observers do usually give ratings of zero, although some trials receive a small non-zero rating. However, in peripheral vision, more zero-difference trials receive non-zero ratings, and the non-zero ratings are bigger than those given foveally. Thus, the distributions of ratings for zero-difference stimuli in foveal and peripheral vision are different. For instance, during one experiment, 11 observers each viewed 23 zero-difference trials, foveally and at 12 degrees eccentricity; the two distributions of 253 ratings were significantly different at $P = 10^{-13}$ (2 sample Kolmogorov–Smirnov statistic = 0.344). This is consistent with the proposed positional uncertainty of peripheral vision coding: observers may not match up the features in the paired images precisely enough to perceive that all parts are identical. However, in rating experiments, observers tend to regress to giving a constant mean rating overall: higher average peripheral ratings for zero-difference stimuli may compensate for the lower peripheral ratings given in general to real differences.

♦ **A new battery of tests to screen for visual recognition problems in neuropsychological**
46 patients
K Torfs, A Conte, B Rossion (University of Louvain)
Although cases of so-called "pure prosopagnosia" are rare, difficulties in face recognition are common (20%) in the neuropsychological population (eg, in posterior brain damage, Valentine et al., 2006; Alzheimer's disease, temporal lobe epilepsy, or autism). The tests mostly used in rehabilitation centers (ie, Benton Face Recognition Test, Warrington Face Memory Test) are old, do not have computerized versions, so response times cannot be measured, and the images contain external features like hair and clothing. More recently, the Cambridge Face Memory Test was developed to assess the variability of performance in face recognition in the normal population. The test has not been developed in a clinical setting and is not validated as a diagnostic tool. Overall, these tests measure different aspects of face perception which overlap only partially. Considering these shortcomings, we developed a battery of behavioral tests tapping into different aspects of face processing, including (1) face detection threshold in noise (2) face matching tasks (3) recognition, and (4) qualitative tests such as the face inversion effect and the composite face illusion. Our freely available battery allows measurement of accuracy and response times, can run on any operating system, is user friendly, and provides summary data for clinicians and researchers. Thus, this battery contributes to neuropsychological diagnosis, and can serve as a basis for the development of neuropsychological rehabilitation programs. In terms of basic research, this tool will lead to a better understanding of face recognition by studying the difference in performance of patients and other participants.

♦ **Bottlenecks when processing motion in multiple objects: The leaky flask model**
47 S Tripathy[1], H Ogmen[2], O Ekiz[2], D Huynh[2], H Bedell[2] ([1]University of Bradford; [2]University of Houston)
The human visual system encodes incoming stimuli and transfers their contents into three major memory systems with increasing time scales, viz., sensory (or iconic) memory, visual short-term memory (VSTM), and long-term memory (LTM). It is commonly believed that sensory memory and LTM have relatively large capacity and the major bottleneck of information processing resides in VSTM, a view that can be characterized as the "hourglass model". In contrast to this view, we show that major bottlenecks for motion processing occur prior to VSTM. We examined bottlenecks of motion processing through a partial-report technique and used variable cue-delays to investigate stimulus encoding, sensory memory and VSTM. We decomposed performance in terms of quality and quantity measures to analyze bottlenecks along these dimensions. In terms of the quality of information, two thirds to three quarters of the motion-processing bottleneck occurs in stimulus encoding rather than memory stages. In terms of the quantity of information, the motion-processing bottleneck is distributed, with the stimulus-encoding stage accounting for one third of the bottleneck. The bottleneck

for the stimulus-encoding stage is dominated by the selection compared to the filtering function of attention. We also found that the filtering function of attention is operating mainly at the sensory memory stage in a specific manner, ie, influencing only quantity and sparing quality. We propose a Leaky Flask Model for information processing that takes into account the bottlenecks that precede VSTM as well as the differential effect of the filtering function of attention on quality and quantity.

♦ **Gaze contingent stimulus presentation for studying holistic processing in face perception**
48 G Van Belle, P Lefèvre, B Rossion (University of Louvain)
Two views traditionally dominated face perception research. Analytical processing on the one hand, suggesting that faces are processed in terms of their individual components, and holistic processing on the other hand, suggesting that facial features are simultaneously perceived and integrated into a single representation, implying a perceptual field covering the whole face. Both views are based on indirect evidence from observations showing interactivity between facial features on the one hand, and an unequal importance of the different features on the other hand. To directly manipulated and observe the type of processing during face perception, and provide an answer to this long-standing discussion, we developed a number of face matching tasks based on gaze contingent stimulus presentation, a technique in which the visual image shown to the observer is updated dynamically and in real time, following the observer's gaze. Selectively masking the centrally or peripherally viewed part of the face, and thereby preventing or forcing feature-by-feature analysis respectively, allowed manipulating the processing strategy during face perception. The size of the perceptual field was assessed using gaze contingent morphing, in which the centrally and peripherally presented parts of a reference face each corresponded to one out of two matching alternatives. We used these paradigms to study the face perception deficit in three acquired prosopagnosic patients and in the face inversion effect and showed that normal face recognition expertise highly depends on intact holistic processing, and that this implies a wide perceptual field, simultaneously encompassing the whole face.

♦ **L-POST: development, validation and norming of a new screening test for perceptual**
49 **organization**
K Vancleef[1], E Acke[1], K Torfs[2,1], C Lafosse[3], J Wagemans[1], L de-Wit[1] ([1]Laboratory of Experimental Psychology, KU Leuven; [2]Université Catholique de Louvain; [3]RevArte, KU Leuven)
Neuropsychological tests of visual perception mostly assess high-level processes like object recognition. Object recognition however, relies on distinct mid-level processes of perceptual organization that are only implicitly tested in classical tests. To fill this gap, we developed the Leuven Perceptual Organization Screening Test (L-POST), in which a wide a range of mid-level phenomena are measured as independently as possible. The L-POST consists of 15 sub-tests screening for various aspects of perceptual organization, such as shape perception, figure–ground segmentation, and is sensitive to several grouping cues, such as common fate, collinearity, proximity and closure. To reduce cognitive load, a matching-to-sample task is used for all test items. Our free online test can be administered in 20–30 minutes, and a neglect-friendly version is available. The test has been validated with 40 brain-lesioned patients for which performance on the L-POST was compared to standard clinic tests of visual perception and other measures of cognitive function to evaluate convergent and divergent validity, respectively. The L-POST showed high sensitivity to visual dysfunction and decreased performance was specific to visual problems. In addition, we collected a norming sample of more than 1200 healthy control participants. In this sample, we observed a decline of L-POST scores with increasing age. No difference was observed between participants who filled in the test with and without supervision of a research assistant. We are now exploring the use of the L-POST in other neurological and psychiatric disorders that have been associated with altered visual perception (eg schizophrenia, dementia, autism). In conclusion, the L-POST is a valuable screening test for perceptual organization. It offers a useful tool for researchers and clinicians to get a broader overview of the mid-level processes that are preserved or disrupted in a given patient.

♦ **Global processing takes time: A meta-analysis on local–global visual processing in ASD**
50 R Van der Hallen[1,2], K Evers[1,3,2], K Brewaeys[1], W Van den Noortgate[4], J Wagemans[1,2] ([1]Laboratory of Experimental Psychology, KU Leuven, Belgium; [2]Leuven Autism Research (LAuRes), KU Leuven, Belgium; [3]Child and Adolescent Psychiatry, KU Leuven, Belgium; [4]Methodology of Educational Sciences, KU Leuven, Belgium)
What does an individual with an autism spectrum disorder (ASD) perceive first: the forest or the trees? 30 years of research on local-global visual processing in ASD has led to influential frameworks

like the Weak Central Coherence (WCC) theory and the Enhanced Perceptual Functioning (EPF) account. Nevertheless, the exact interplay of local and global visual processing in ASD remains only partly understood. Research findings vary in indicating a local processing bias or a global processing deficit, and results often bluntly contradict each other. Here, we have applied a formal meta-analytic approach, and combined 56 articles on the perception of local and global order in ASD using a wide range of stimuli and tasks. Compared to typically developing (TD) individuals, individuals with ASD show no enhanced local visual processing nor an overall deficit in global visual processing. However, detailed analysis does yield a clear difference in the temporal pattern of the local–global interplay, ie, slower perception of global order in ASD. Gender, age or IQ of either participant group does not seem to influence performance differentially. Although several important moderator variables have been included in the present study, new experimental research is necessary to identify more clearly which (other) variables are at play and how the temporal pattern of global order perception precisely differs for individuals with ASD compared to TD.

♦ **Cognitive architecture of visual perceptual organization**

51 P A van der Helm (University of Leuven, Belgium)

I present a cognitive-architecture model of the visual hierarchy in the brain. According to this model (1) visual perceptual organization comprises three intertwined subprocesses, namely, feedforward extraction of visual features, horizontal binding of similar features, and recurrent selection of different features, (2) resulting percepts reflect hierarchical stimulus organizations, and (3) task-driven attention predominantly subserves top-down scrutiny of the hierarchical structure of established percepts. I discuss how this model relates to (a) neuronal synchronization as manifestation of transparallel processing, which, in classical computers, is as powerful as quantum computers promise to be, and (b) visual masking and its break-down in autism.

♦ **Connective field mapping in a hemispherectomized patient**

52 M van Dijk[1], N Gravel[1], K V Haak[2,3], N M Jansonius[1], P van Dijk[1], F W Cornelissen[1] ([1]University Medical Center Groningen; [2]Radboud University Nijmegen; [3]Donders Institute for Brain, Cognition and Behaviour, Nijmegen)

The human visual cortex contains maps of the visual field. Much research has been dedicated to answering whether and when these visual field maps and their connections change if critical components of the visual circuitry are damaged. In a previous study (Haak et al., 2013), our group used population receptive field (pRF) mapping (Dumoulin & Wandell 2008) to study the retinotopic organization of a 16-year-old hemispherectomized girl. Her left hemisphere was removed at the age of 3 as a treatment for chronic focal encephalitis (Rasmussen syndrome) and intractable epilepsy. In line with the hemispherectomy, Goldmann perimetry showed a homonymous right hemianopia. Whereas the pRF mapping indicated normal visual field maps in the early visual cortex, the maps in the extrastriate cortical areas contained an enlarged foveal representation and much smaller population receptive fields compared to normal. Here, we applied connective field modeling (Haak et al., 2013) to the functional data of this patient. This method models the responses of voxels in one part of the brain (eg, V2) as a function of activity in another part of the brain (eg, V1). Preliminary analyses indicate that while there are substantial regional differences, the connective fields on V1 of the hemispherectomized patient are—on average—relatively small compared to those in three control participants (six hemispheres). This finding suggests that the origin of the smaller extrastriate pRFs may lie in a deviant cortico-cortical connectivity.

♦ **On shading-like cues**

53 A van Doorn[1], J Koenderink[2], L Albertazzi[3], J Wagemans[2] ([1]University of Utrecht; [2]University of Leuven; [3]University of Trento)

Shape From Shading has a venerable history, especially in the arts, but also in vision science. It depends upon the shading cue, which has strong ecological roots, and a formal physical theory. Lambert's law states that the irradiation of a surface depends causally on its obliquity with respect to the direction of irradiation, and terrestrial ecology implies that the irradiation tends to come from above. Yet, the case of shading is similar to that of perspective, in that artists eventually fought themselves free of it. In the decades straddling 1900, a variety of alternative "shading" methods arose. These are best typified as "cues to relief articulation", because Lambert's law plays no role. These cues arise from two different principles, which often occur in combination. One is that the toning of areas can be replaced with the articulation of the boundary between areas. The other is that tonal variations can be replaced with

chromatic variations. Some of these methods are ancient, for instance "edge darkening"—often seen in sculptor's drawings—is more ancient than "shading". It is often preferred in religious art, because it obviates the choice of an arbitrary direction of irradiation. We compare the "power" of a number of such cues, using the power of shading in various contrasts as "anchor points". The alternative cues are on a par with the shading cue proper, putting doubt on the credibility of its "ecological explanation".

♦ **The effect of stimulus predictability on the representations of local features in apparent**
54 motion
N Van Humbeeck, T Putzeys, J Wagemans (University of Leuven)
Perceptual grouping has been shown to suppress low-level representations of local visual features when these features are part of a predictable spatio-temporal configuration. This finding has been explained in the context of predictive coding theory, in which lower-level neural activity is "explained away" by an enhanced higher-level representation. However, it has been observed that a predictable spatio-temporal context induced by apparent motion results in an increase in V1 activity for stimuli which are located along the illusory motion path [Muckli et al., 2005, PLoS Biology, 3(8): e265]. This seems to be inconsistent with the predictive coding scheme, but rather reflects a motion-related filling-in process in lower-level visual areas by feedback from higher-level areas. In the present study, we investigated the effect of apparent motion on the neural representations of local features. We found decreased detection performance along the apparent motion path, suggesting an increase of V1 activity interfering with the representations of stimuli presented on the path. The temporal predictability of the presented stimuli did not influence this masking effect.

♦ **Orientation-specific perceptual suppression**
55 M Vergeer, R van Ee, J Wagemans (Laboratory of Experimental Psychology, KU Leuven)
Perceptual suppression phenomena are frequently used to study the concept of consciousness in general and, more specifically, the mechanisms involved in perceptual selection. Here we are interested in common mechanisms underlying monocular and binocular suppression. We previously obtained evidence for feature-selectivity in binocular suppression (Vergeer and van Lier, Vis Res 2010). Here we focus on feature-selectivity in Motion-induced Blindness (MiB) and classic perceptual fading. In both paradigms, a peripherally presented target disappears perceptually after prolonged fixation. In perceptual fading the target is commonly presented on a static homogenous background, whereas in MiB competition for awareness occurs between a static target and a dynamic mask moving across the visual field, although they never physically overlap. In grouping effects found in these phenomena, as in binocular rivalry, it is difficult to distinguish the role of attention from a possible intrinsic stimulus-specific suppression mechanism. Here we look at feature-based effect in a more direct manner. In both tasks, a peripherally presented oriented Gabor was removed from the screen after its perceptual disappearance and a test grating appeared left or right of the previous target location. For both phenomena, an adaptive QUEST procedure revealed significant elevated contrast detection thresholds when the test and target stimuli had the same orientation compared to when they were orthogonal, indicating feature-specificity. These results emphasise the similarity between different monocular and binocular bistable phenomena. We argue that common perceptual mechanisms are in place at the monocular and the binocular level.

♦ **Pictorial reliefs as organizations of categorically perceived local surface shapes**
56 J Wagemans[1], A Van Doorn[2], J Koenderink[1] ([1]University of Leuven; [2]University of Utrecht)
When looking at pictures of 3D objects, the perception of surfaces articulated in depth appears as a continuous spatial array of local surface shapes. This "pictorial relief" emerges only gradually in awareness, when disambiguating local luminance gradients and edge fragments, that are mixtures of intrinsic shape variations as well as extrinsic variations due to light source position and viewing direction. This microgenesis involves perceptual organization of neighboring regions from the image, in combination with geometric assumptions and object knowledge. We studied pictorial reliefs of three observers looking at a photograph of a sculpture of a reclining nude, by probing a large number of locations with a continuous "shape index" scale (Exp. 1) and a version with only the five major shape categories: cap, ridge, saddle, rut, cup (Exp. 2). While the continuous judgments were difficult and time-consuming, the categorical distinctions quickly appeared in visual awareness. Judgments in the hyperbolic regions of the stimulus (eg, the waist area) were more variable than in the elliptic convex or concave regions. Hence, the elliptic convex parts play a major role in the microgenesis of pictorial relief, while the hyperbolic parts appear as a kind of "glue" between the convex parts or a

kind of "background" to them. This explains why the category of a saddle shape was omitted from the taxonomy of local shapes by Alberti (1436). However, the geometrically more appropriate taxonomy by Gauss (1827) is too rich, since human observers use it only categorically in their spontaneous perception of pictorial relief.

♦   **Comparison of behavioral and eye movement responses in crowding**
57   F Yildirim, F W Cornelissen (University Medical Center Groningen)
Crowding is an ambiguity in the peripheral vision that occurs when a target is surrounded by other— similar—objects. Crowding is typically studied using manual responses. Peripheral vision, however, is used for planning eye-movements. This begs the question whether crowding as measured when participants respond with their eyes is different from when they respond by hand, while fixating. On top of that, recent reports suggest either reduced or increased crowding around saccade initiation. If such effects would significantly influence crowding this would be important to know. In this experiment, 8 participants viewed stimuli that contained a reference and a target (an oriented target Gabor) that were positioned either left or right of a central fixation point. Participants were asked to indicate the position of the target (the right most tilted one). Conditions involved presenting isolated reference and target, as well as conditions in which both were surrounded by identical flankers. Participants performed the task while either responding via a button response or via eye movements. Results revealed that responding by eye or by hand did not make a difference in target localization performance. Response times were also similar. Hence, for all practical purposes, crowding can be considered identical for either type of response.

♦   **Motion camouflage in zebras: Computational modelling**
58   J Zanker[1], M How[2] ([1]Royal Holloway University of London; [2]University of Queensland)
High contrast periodic skin patterns, such as the stripes of the zebra raise interesting questions of evolutionary benefits, and have been source of debate and speculation ever since Charles Darwin and Alfred Russel Wallace first disagreed on the subject. Within the wide range of theories that have been put forward, we previously supported the idea that the stripes act to confuse or 'dazzle' observers, considering some fundamental properties of motion processing mechanisms—here, we are presenting a set of computer simulations (using a variety of zebras images and control images from un-patterned horses) to demonstrate in detail how the computations of a typical visual system will lead to substantial estimation errors for locale velocity distributions. The effects are related to the well know perceptual phenomena of 'wagon-wheel effects' and 'barber-pole illusion', and most importantly will interfere with the observer's ability to detect, segment, recognize, and pursue animals covered with such skin patterns. Because this would obviously diminish the chances of a predator to catch their prey, there could be a string evolutionary pressure to develop surprisingly conspicuous patterns such as zebras stripes.

♦   **Perception of visual configuration in apparent motion displays is predicted**
59   **by spatiotemporal contrast sensitivity**
      A Zharikova[1], S Gepshtein[2], C van Leeuwen[1] ([1]Laboratory for perceptual dynamics, KU Leuven; [2]Systems neurobiology laboratories, The Salk Institute for biological studies)
Previous studies suggested that spatiotemporal contrast sensitivity (Kelly, 1979) can predict perceptual organization in apparent motion displays (Gepshtein & Kubovy, 2007). Here we test this hypothesis by comparing conditions of equivalent contrast sensitivity and conditions of equivalent spatiotemporal grouping. Individual spatiotemporal contrast sensitivity was assayed in a direction discrimination task using drifting luminance gratings. Estimates of sensitivity were then converted from the domain of spatiotemporal frequencies to the domain of spatial and temporal distances between elements in apparent motion stimuli. We asked whether the equivalent spatiotemporal distances corresponded to conditions of equally strong spatiotemporal grouping. The latter was estimated using ambiguous stimuli that consisted of several rotating dot pairs ("dipoles") distributed evenly on an imaginary circular contour. The stimuli could be seen either as multiple rotating dipoles or as a single pulsating circular contour (Anstis & Kim, 2011). We found the conditions of equivalent spatiotemporal grouping where the two percepts were equally likely. From the spatial distances under equivalent contrast sensitivity we predicted the spatial distances of equivalent spatiotemporal grouping. The predicted and measured distances for equivalent spatiotemporal grouping were highly correlated. These results support the view that spatiotemporal contrast sensitivity and perception of spatial configuration in apparent motion displays are governed by the same constraints.

AUTHOR INDEX