**PROGRAMME**

**RESEARCH GROUP WORKSHOP**

**Eye Tracking Methods and Scan Path Analysis**

Convenors: Prof. Dr. Wolfgang Einhäuser-Treyer (Marburg), Prof. Dr. Kenneth Holmquist (Lund)

**March 6-7, 2013**

Room: Plenarsaal

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**Tuesday, March 5, 2013**

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**From eye cups to tea cups: a brief history of eye tracking**

Ben Tatler

*School of Psychology, The University of Dundee, Scotland*

The saccade-and-fixate strategy, associated with voluntary eye movements, was first uncovered by Wells in the late 18th Century in the context of involuntary eye movements following body rotation. In this context, objectively revealing the movements of the eyes using afterimages was key to understanding how the eyes moved. By the late 19th Century a variety of devices for measuring eye movements were emerging and these typically used levers to connect an eye cup - made of ivory, aluminium or plaster-of-Paris - attached to the surface of the eye to a recording surface such as a smoked drum. However, the inertia associated with eye cups made recordings inaccurate and experiments uncomfortable. A significant advance in this respect was made in the early 20th Century when Dodge and Cline introduced a photographic technique for measuring eye movements based on light reflected from the surface of the eye. Alongside the technological development of eye trackers throughout the 20th Century came their widening use in scientific research from reading, to pattern viewing, to complex scene viewing, and eventually to real world behavioural settings. The first mobile tracker was developed by Hartridge and Thompson in the late 1940s and refined by Shackel, Mackworth and Thomas in the 1950s. Despite elegant work using this tracker during driving and walking, it was not until the 1990s when mobile eye tracking began to assume a prominent role in psychological research. The recent popularity of studying eye movement behaviour in the context of natural tasks owes much to the pioneering work of Land, Ballard and Hayhoe in the early 1990s.

**Head-mounted eye tracking in infants, children, and adults**

John Franchak,

*Department of Psychology, New York University, USA*

Many developmental psychologists rely on paradigms that use infants' looking behavior as the primary measure. Despite hundreds of studies describing infants' visual exploration of experimental stimuli, researchers know little about where infants look during everyday interactions. Head-mounted eye trackers have provided many insights into natural vision in adults, but current methods and equipment that work well with adults are not suitable for infants. In this talk, I outline the first method for studying mobile infants' visual exploration and present a series of studies that examined the eye movements of infants, children, and adults during natural interactions. Results reveal that, over the course of development, visual guidance of obstacle navigation shifts from foveal to peripheral control, with adults relying primarily on peripheral vision to guide locomotion over obstacles. Moreover, constraints of body posture affect visual exploration in both motor and social situations.

**The dynamic coupling of hands and eyes: A dual eye tracking of visual attention in parent-child interactions**

Chen Yu

*Department of Psychological and Brain Sciences, Cognitive Science Program and Department of Computer Science, Indiana University, USA*

I will present two studies on coordinated visual attention. In the first study, 13-month-old infants and their parents were fitted with head-mounted eye trackers that recorded their momentary gaze data in a dynamically complex interaction of manual engagement with multiple toy objects. The results show that the dynamic structure of parent's and infant's attention systems are quite different as the parent frequently and rapidly shift fixations to monitor all the objects potentially in play as well as the infant's face whereas the infant's attention system is slower with longer looks to objects, fewer attention shifts; and very few fixations on the parent's face. Despite these different dynamics and despite limited looks to the parent's face by the infants, the parents and infants nonetheless tightly coordinate their visual attention on the same object with coordinated adjustments that occur in fractions of second. This achievement of coordinated visual attention exploits the links between eyes and hands, through multiple pathways as a system of sensorimotor couplings involving eyes, head and hands within and across dyads. Next, I will present a gaze-contingent design
using a robot as an embodied model, in which we systematically manipulated the robot's gaze to the human partner's face in real time and then analyzed the human's gaze behavior as a response to the robot's gaze behavior.

**WEDNESDAY, 16:00**

**Studying oculomotor behavior in natural tasks: Instrumentation and analysis tools for mobile observers**

Jeff B. Pelz

*Multidisciplinary Vision Research Laboratory, Chester F. Carlson Center for Imaging Systems, Rochester Institute of Technology, Rochester, New York, USA*

The ‘tasks’ employed in the study of task-driven vision range from responding to single-step stimuli on a laboratory display to complex natural tasks performed by mobile observers. New instrumentation allows the collection of gaze data from mobile observers in natural environments, but software tools for analyzing gaze data from mobile observers in dynamic environments have not kept pace.

I will provide a brief history of instrumentation and methods used to collect gaze data from mobile observers, review the methods that have been developed to analyze the data collected, and describe our current research aimed at expanding the range of tasks that can be studied by improving both collection and analysis tools.

**WEDNESDAY, 17:15**

**Examination of Eye Movements and Natural Visual Exploration: Taking EyeSeeCam from Bench to Bedside and into the Field**

Erich Schneider¹,², Günter Kugler², Klaus Bartl², Stefan Kohlbecher², Stanislavs Bardins², Doreen Huppert², Nadine Lehnen², Thomas Brandt²

¹Lausitz University of Applied Sciences, Senftenberg, Germany; ²German Center for Vertigo and Balance Disorders, University of Munich, Germany

EyeSeeCam is a gaze-controlled, head-mounted video camera that records the true input to the visual system: retinal content. This functionality incorporates active visual exploration by saccades with image stabilization during head, object, and surround motion, just as occurs in human ocular motor control. EyeSeeCam thereby enables studies on human gaze behaviour under dynamical and ecologically valid conditions such as during free locomotion in natural environments.

The system consists of a binocular 3D eye tracker that runs at a sampling rate of up to 600 Hz and a camera motion unit with up to three piezo actuators in a parallel kinematics setup. This setup achieves angular velocities of 3500 deg/s at a bandwidth of 20 Hz. All image processing, data analysis, and video recording tasks are performed on a mobile computer. This computer is connected via one cable to the lightweight head mount that carries four cameras and the actuation mechanics. The total system delay is 9 ms, which comes close to the image-stabilizing properties of the human vestibulo-ocular reflex (VOR), the fastest reflex in vertebrates. The analysis of the VOR is a key element of the diagnosis in patients with vertigo. Usually, quick head rotations with high accelerations (3500 deg/s.s) and high velocities (300 deg/s) are applied in order to detect the presence or the (pathological) absence of the image-stabilizing counter-rotations of the eyes. In a classical eye tracker, these head impulses can cause slippage artefacts. With a lightweight (60 g) version of EyeSeeCam, this test can now routinely be carried out at the bedside.

In addition to this medical application, EyeSeeCam has also been used in a number of studies on eye-head coordination and gaze behaviour in both natural settings, ranging from offices over urban areas to deserts, and in classical laboratory settings. In a study on visual search of coloured candies on a lawn, a comparison of deuteranomalous with normal gaze behaviour showed that humans do not use negative preselection as a strategy, i.e., they do not suppress fixations on task-irrelevant targets. This was additionally confirmed in a classical lab setting. In another study carried out on a balcony 15 m above ground level we found that subjects with height intolerance showed significantly reduced eye and head movements and, hence, less visual inspection of the visual surround as compared to controls. An overview of studies will be provided that have been carried out with EyeSeeCam at the bedside and in the field.
**THURSDAY, 9:15**

**Eye movements in scene perception: from the lab to the real world**

**Tom Foulsham**

*Department of Psychology, University of Essex, UK*

Unlike the simple stimuli used in many traditional cognitive neuroscience experiments, natural scenes and situations provide a context which is complex, dynamic and semantically rich. In the first part of the talk I will review experiments investigating the control of gaze in participants viewing photographs of natural scenes in the lab. Although feature contrast and visual saliency may predict where people look in some instances, observer knowledge of objects and task goals seem to be more important. Furthermore, experiments investigating memory and the reliability of scanpaths over time suggest that top-down influences on gaze are idiosyncratic.

In the second part of the talk I will consider recent experiments which record where people look when free to move around the real world. This methodology provides a test of the assumption that looks to a picture in the lab inform us about visual and cognitive processing in real life. Across studies involving free exploration, visual search and social interaction, these experiments provide powerful new data for investigating natural active vision.

**THURSDAY, 10:00**

**The effect of task difficulty on eye movement sequences in multiple dimensions**

**Richard Dewhurst, Marcus Nyström, Halszka Jarodzka, Tom Foulsham, Roger Johansson, Kenneth Holmqvist**

*Humanities Lab, Lund University, Sweden*

There are several reasons why eye movement researchers are interested in quantifying the effect of task difficulty on scanpaths. First, this allows us to gauge the suitability of educational software; if the implementation is too hard, what kinds of eye movement sequences are associated? Second, the task can be difficult for different reasons, some higher-level (cognitive) some lower (visual); understanding the relationship between these allows us disambiguate top-down from bottom-up influences on the oculomotor system (e.g. Foulsham, Barton, Kingstone, Dewhurst, and Underwood, 2011). Until recently however, studying the effect of task difficulty on eye movements has been limited either to unitary eye movement events (fixations and saccades in isolation (Wertheim, Hooge, Krikke, and Johnson, 2006)), or coarse averaging across many eye movement types (with attention maps (Grindinger, Duchowski, and Sawyer, 2010), and transition matrices (Holmqvist, Holsanova, Barthelson, and Lundqvist, 2003)). Here we present new data showing the effect of task difficulty on scanpaths as measured by our multidimensional scanpath similarity approach—MultiMatch (MM: Jarodzka, Nyström, and Holmqvist, 2010). This has the advantage of capturing sequence information, whilst retaining fundamental eye movement parameters like fixation position, duration, and saccadic amplitude. It also controls for scanpath shape, which can differ depending on the task at hand (e.g. Johansson, Holsanova, and Holmqvist, 2011).

Three experiments evaluated scanpath similarity with respect to task difficulty in different ways. In each experiment participants were presented with the numbers 1-5 and their task was to saccade to each number in order. In Experiment 1 the numbers were of different size per trial, according to five levels of task difficulty (small to large). In Experiment 2 the numbers were presented along with a varying number of distractors, giving five set sizes (1-6: 1-10), easy to difficult. Experiment 3 introduced noise by degrading the background in five steps relative to the numbers themselves, making them harder to identify in peripheral vision. Task difficulty was manipulated under these conditions according to the hypothesis that when the numbers are less conspicuous, participants will produce more divergent scanpaths between individuals. This was assessed both with our MM scanpath similarity metric, and with the most advanced alternative—ScanMatch (SM: Cristina, Mathot, Theeuwes, and Gilchrist, 2010).

Results revealed that scanpaths do indeed become less similar as the task becomes harder, but critically this depends on the task. Smaller numbers are harder to locate, but the larger margin of spatial error for fixating bigger numbers leads to scanpath variability. Conversely, larger set sizes are more difficult, with decreasing similarity in terms of position and shape as task difficulty increases. However, the oculomotor system compensates with a greater number of shorter fixations, actually improving performance accuracy. Only when the task was made harder with increasing background noise, were both the oculomotor and scanpath comparison measures consistent, both for our multidimensional method and for ScanMatch.

Behavioural results are presented along with absolute similarity scores of MM and SM, and also classification scores showing the ability of the two scanpath comparison measures to capture whether participants are looking at the same or different stimuli as a function of task difficulty.
Scanpath similarity in real-world tasks: A sub-action sequenced linear distance method
Rebecca M. Foerster, Elena Carbone, Hendrik Koesling, Werner X. Schneider
Neurocognitive Psychology, Bielefeld University, Germany

Measures of scanpath similarity are essential in many research domains. Traditional methods compare fixations within a scanpath according to their numerical and more recently temporal position within the paths. These procedures are reasonable when the to-be-compared scanpaths are executed in response to a relatively stable visual input, e.g., picture viewing. In real-world tasks, however, trial completion times are invariant and stimuli viewing times are uncontrollable because participants actively change their environment while performing the task. When comparing scanpaths, fixations of one and the same sub-action can have a different index in the two paths and are executed at a different interval after trial onset. Traditional methods would inadequately compare fixations within scanpaths that have been executed at totally different sub-actions. Using the sub-actions as structuring units, a functional matching procedure for determining scanpath similarity had been developed (Foerster et al., 2011). This procedure evaluates the similarity of scanpaths according to the comparison of fixations that have been performed during the same sub-action of a sensorimotor task. Similarity values are evaluated by testing them against random similarity values calculated based on the same data set. In sum, the method reveals whether participants’ eye movements are similar when they are engaged in the same sub-action, opposed to when they are engaged in different sub-actions. Comparing this method with traditional scanpaths similarity methods reveals the strength of the functional matching procedure in the context of real-world tasks.

Scanpaths: What determines where the eyes look next?
John M Findlay
Centre for Vision and Visual Cognition, University of Durham

This talk will largely review data collected some years ago and published as Findlay and Brown, Vision Research, 2006. We recorded scanpaths as participants carried out a visual search task scanning through a set of near-identical items, the numbers of items on different trials varying between 3, 6, 9 and 12. Errors were infrequent with small item numbers but increased to about 25% with 12 items. Individual saccades were accurately directed at items, although the accuracy decreased with the presence of nearby distractors. Immediate backtracking was quite common but backtracking further in the sequence was rarely found. All participants showed evidence of using some heuristic strategy to decide the order of scanning items, but strategies differed considerably, some resulting in raster-like patterns, others showing reliance on the overall external contour.

A new method for analyzing scanpaths
Titus von der Malsburg
Department Linguistik, Universität Potsdam, Germany

Scanpaths have not played an important role in reading research. This is surprising given that pioneering work in the field has shown that scanpath patterns can be informative about language processing (Frazier & Rayner, 1982). One reason why research on scanpaths in reading has not gained much traction may have been a lack of suitable tools for analyzing scanpaths. Reading research mostly relied on a conventional set of simple eye-tracking measures that quantify, e.g., the fixation duration on a word or the probability to move backwards form a word. While this approach has been hugely successful, there are also problems that have resisted being solved with these tools. Here is one such problem: When the reader, in an temporarily ambiguous sentence, is mislead to adopt an interpretation that later in the sentence turns out to be incorrect, how does the language system revise its analysis of the input? Previous research suggested that this revision process consists of several steps which are reflected in the trajectory of the gaze across the sentence (Frazier & Rayner, 1982; Meseguer, Carreiras, & Clifton, 2002; Mitchell, Shen, Green, & Hodgson, 2008). The traditional word-based measures capture only fragments of these trajectories and are therefore difficult to interpret and potentially misleading. In my presentation, I will demonstrate a new method for analyzing eyetracking data that analyzes scanpaths as a whole (von der Malsburg & Vasishth, 2011, 2012; von der Malsburg, Vasishth, & Kliegl, 2012). The method is based on a similarity measure for scanpaths that is highly sensitive to spatial and temporal propertie of scanpaths. When we used this measure to conduct a cluster analysis of reading patterns, we found reading strategies for temporarily ambiguous
sentences that were missed in earlier studies and could show that readers respond to these sentence in qualitatively different ways. In a related corpus study, we investigated how various factors jointly determine the regularity of scanpaths in reading (von der Malsburg, Kliegl, & Vasishth, 2012). Taken together our results establish the scanpath as an informative and tractable object of investigation in reading research. Since no reading-specific assumptions have been made in the design of our scanpath measure, it can also be used to analyze other kinds of eye movement data, which opens the door to innumerable applications in research fields such as scene perception, visual attention, problem solving, and usability research, to name just a few.


**THURSDAY, 16.00**

**Overt and covert attention during grasping of objects**

René Gilster

*Allgemeine und Experimentelle Psychologie, Department Psychologie, Universitaet Muenchen, Munich, Germany*

We investigated overt and covert shifts of attention during manual grasping movements. In the first set of experiments, subjects fixated the center of cylindrical objects while grasping them with thumb and index finger. A perceptual discrimination task was used to assess the distribution of visual attention prior to the execution of the grasp. Results showed enhanced discrimination for those locations where index finger and thumb would touch the object, as compared to the action-irrelevant locations. A same-different task was used to establish that attention was deployed in parallel to the grasp-relevant locations. In a second set of experiments, we contrasted covert attentional allocation with overt attention. Eye fixation behavior was compared during grasping and pointing to a location at the rim of the cylinder. During pointing, the eye fixated at the movement goal. In the grasping condition however, preferred eye fixations were located close to the center of the object. Thus, while covert attention seemed to split to the action relevant locations, the eyes tended to fixate the center of the object, reflecting a dissociation between overt and covert attention during grasping. The findings are consistent with the conjecture that the planning of complex movements enacts the formation of a flexible "attentional landscape" which tags all those locations in the visual lay-out that are relevant for the impending action.

**THURSDAY, 16.45**

**Neural correlates of fixation, saccadic and pursuit eye movements**

Mark W. Greenlee

*Institute of Experimental Psychology, University of Regensburg Germany*

As we inspect dynamic real-world scenes, our eyes move to quickly shift fixation to different objects of interest. Often these objects are in motion and/or we are moving, challenging our ability to stabilize fixation. I would like to present the results from a series of functional MRI experiments, in which we asked participants to fixate a stationary target presented on a background (Tse et al. 2010), to track moving targets (Acs & Greenlee, 2008), or to saccade to the remembered locations of targets (Raabe et al., 2013). Adjustments of saccadic gain take place when saccades repeatedly overshoot the eccentric target. We discuss how gain changes (saccadic adaptation) are reflected in differential neural activity in supplementary and frontal eye fields (Blurton et al., 2011). Together these studies reveal a neural network in posterior and frontal cortex that underlies the dynamic control of voluntary eye movements to objects in complex scenes.


The Effect of Language on the Horizontal Asymmetry in Overt Attention

Zaeinab Afsari¹, Jose P Ossandon¹, Matti Krüger¹, Matthias Hampel¹, Peter König¹,²

¹Institute of Cognitive Science, University Osnabrück; ²Institute of Systems Neuroscience, University Medical Center, Hamburg Eppendorf

Attentional asymmetry was first reported on hemineglect patients. Subsequent studies demonstrated a lateral asymmetry in healthy subjects as well. Here, we explore the influence of direction of writing on the phenomenon of attentional asymmetry. Subjects were reading text primes and subsequently freely viewed natural scenes while eye movements were recorded. Primes involved texts written in primary or secondary language using right-to-left (RTL), left-to-right (LTR), or mirrored left-to-right (mLTR) text samples. Target images are comprised of natural, urban and fractal pictures. Experiment 1 investigates the effect of reading direction in bilingual participants with RTL (primary) and LTR (secondary) texts primes. In the first second after onset of the target images, subjects displayed a rightward shift after reading a RTL prime. In contrast, after reading a LTR prime a leftward bias was observed. After the first second, the bias was largely reduced up to the end of target presentation to be close to the center of the images. This result suggests that reading direction of a text prime influences later exploration of complex stimuli. In experiment 2, we investigated whether the difference of primary and secondary language influences the results. For this purpose, we measured German/English bilinguals with LTR reading direction texts in both languages. Here, participants showed leftward bias after reading LTR texts in either case. This demonstrates that for the present purpose, the difference between primary and secondary language is not important. In the final experiment, we investigate the relative influence of principal and actual reading direction. LTR bilingual participants were presented with normal and mirrored LTR texts. Upon reading the primes, reading direction differed markedly, reflecting mirrored and not mirrored conditions. However, we did not observe significant differences in the leftward bias. This experiment demonstrates that the principal, not the actual reading direction influences the asymmetry on later complex target images. In conclusion, our results revealed that there is an influence of language direction- not the scanning direction- on viewing behavior of complex images that do not contain text elements.

Automatic Analysis of 3D Gaze Coordinates on Scene Objects in an Everyday Observation-Driven Scenario

Kai Essig, Jonathan Maycock, Daniel Prinzhorn, Helge Ritter and Thomas Schack

Abteilung Sportwissenschaft, Neurokognition und Bewegung – Biomechanik, Universität Bielefeld, Germany

We present a method which removes the need for manual annotation of eye-movement data. Our software produces as output object and subject specific results for various eye-tracking parameters in complex 3D scenes (Essig et al., 2012). We synchronized a monocular mobile eye-tracking system with a VICON motion-capture system. Combining the data of both systems, we calculate and visualize a 3D gaze vector within the VICON coordinate frame of reference. By placing markers on objects and subjects in the scene, we can automatically compute how many times and where fixations occurred. To test our implementation we designed a simple experiment, in which subjects had to observe a human demonstrator performing two everyday tasks, preparing a mug of coffee and a mug of hot chocolate (Maycock et al., 2012). The observer’s eye movements were tracked using a mobile eye tracker and the demonstrator hand and all objects were tracked using Vicon. Our results support early finding by Mataric and Pomplun (1998) that people typically follow the hand or the object in the hand that is moving. However as our experiments involved complex interaction scenarios, such as making a mug of coffee, we also observed jumps in the focus
of attention to objects that were about to be acted upon. These patterns reflect similar ones recorded from the point of view of the executor of a task and are thought to help with path planning and finding suitable landing points for grasps. The fact that observers do this too adds to the growing body of evidence for the strong sensori-motor integration in the brain.

Impact of Emotions During Free-viewing Task on News Webpages
Ricardo R. Gameiro, Kai Kaspar, Peter König
Department of Neurobiopsychology, Institute of Cognitive Science, University of Osnabrück, Germany

In this study our aim was to investigate the effect of emotions on attentional attraction during a free viewing task. Previous studies have shown that emotions may lead to differences in viewing behavior on one specified target stimulus. This experiment, however, does not provide a simple target but two different main targets at the same time from different categories - positive and negative. Having this design makes it possible to examine whether emotional priming leads to different selectivity preferences towards one of the two targets within the same task. To make the experiment as ecologically valid as possible, we used homepages with one positive and one negative main news (positive and negative target respectively) in the center of the screen.

Participants were divided into 2 equally sized groups where group one was primed with positive pictures whereas for the other group negative pictures were taken. Stimuli were taken from the IAPS database according to their valence factor. Afterwards self created news homepages have been shown to the participants in a separate task while eye movements were recorded. Both groups saw the same homepages containing two main fake news pictures - also taken from the IAPS dataset - each and several distractors such as advertisements, sport scores and random news text. At the end of the study the participants were asked to fill out a questionnaire to rate the presented homepages’ appeal, pragmatic quality and hedonic qualities as well as a recall questionnaire to state memorized pictures of the main news.

The results show that those participants being positively primed show a higher tendency to rate the presented homepages more appealing than the negatively primed group. Furthermore repeated measurement ANOVAs show that there is a significant effect between the interaction of priming condition and valence of the target pictures in the recall questionnaire saying that the positive priming groups memorized more negative than positive news over the complete task. For the negative priming group this effect was found to be much smaller. This finding is also significant in the eye tracking data, mainly in the number of fixations within a single IAPS picture (see figure 1) and other factors: saccades towards & within pictures and dwelling time. In addition an interactive effect between the position of the IAPS picture on the webpage (left vs. right) and its valence was found according to the mean fixation
duration within each target. It shows that across both priming groups positive pictures placed on the left reveal shorter fixation duration than positive pictures presented on the right side and vice versa for negative stimuli. (see figure 2)

There is a strong evidence based on our results that visual attention and can be inuenced by emotional priming. Not only provided by pure eye tracking data but also in the subjective results (recall questionnaire) by the participants. Based on these findings including the significantly different rating of appeal and the fact that the stimuli were ecologically valid news homepages, might make it important for webpage designers to take emotional states of their customers into account.

Visual attention during real-world decision making
Kerstin Gidlöf

Humanities Lab, Lund University, Sweden

In this project we attempt to bring together the eye tracking research performed in natural environments with the attempts to trace a decision-making process. Almost all decisions we make involve acquisition of visual information but decision-making is a special kind of task where the information is valued very differently in each case. For each case, the kind of information needed to complete the task might differ largely due to different preferences or goals. One piece of information might be crucial for one person but not at all interesting to another. This calls for a new set of eye tracking measures that can be used to compare one cognitive process to another without relying on exactly what is being visually attended to. For this project, we sought to study consumers’ decision making in its natural context: the supermarket. The aim is to uncover the timeline of gaze behaviour in a decision-making task and to device a model of the decision making process based on this information. How does the process of making a decision influence eye movements in the natural setting of the supermarket? We present a model to segment the decision process in to different stages. This model enables us to take a closer look at how the decision making process unfolds over time and its relation to visual attention. We will also present future studies in this direction which will be based on this segmentation model.

Gaze Behaviour with Height Intolerance
Günter Kugler1, Doreen Huppert1, Erich Schneider1,2, Klaus Bartl1, Stefan Kohlbecher1, Thomas Brandt1

1German Center for Vertigo and Balance Disorders, University of Munich, Germany 2Lausitz University of Applied Sciences, Senftenberg, Germany

Visual exposure to height generally causes instability and in about 28% of humans it causes distress. We addressed the question of whether the phenomena of height intolerance correlate with changes in gaze behaviour during height exposure under natural conditions of locomotion and upright stance.

EyeSeeCam was used to examine the head-eye coordination of 19 control participants and 18 participants with height intolerance. The experiment took place on an escape balcony located on the 4th floor, i.e., 15 meters above ground level. The balcony had a thin balustrade providing safety while at the same time ensuring visual exposure to height. The participants stood upright looking into the vertical depth below for 30 seconds. They were instructed to stand close to the balustrade without touching it. In addition, participants had to perform a locomotion task. During upright stance, visual exploration was spatially limited in the height intolerant group. In some subjects horizontal exploration only was observed; in extreme cases, gaze remained fixed most of the time. Head movements were also significantly reduced (p=0.003).

The distress experienced by the height intolerant person affects oculomotor behavior and leads to less inspection of the surrounding environment. This can increase the risk of stumbling and ultimately of falling.

Oculomotor markers in freely moving patients differentiate progressive supranuclear palsy from idiopathic Parkinson's disease efficiently and robustly
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Progressive Supranuclear Palsy (PSP) is a progressive neurodegenerative disease characterized by postural instability, frontal dementia and supranuclear gaze palsy. It is widely misdiagnosed as Parkinson’s disease (PD), but an early differential diagnosis is essential for adequate treatment. Oculomotor dysfunction is essential to diagnose PSP, but frequently unrecognized by mere clinical examination. To quantify oculomotor functions, we asked PSP-patients (N=10), PD-patients (N=11) and healthy controls (HC, N=10) to conduct a standard fixation protocol consisting of 5 specified red dots projected onto a plain wall which had to be
fixated one after the other. Thereupon they were asked to walk up and down a corridor, while their eye movements were recorded with a wearable gaze-tracking system ("EyeSeeCam").

PSP-patients showed significantly reduced saccade amplitudes, and significantly reduced saccade velocities as compared to PD-patients and HCs during the fixation protocol. These restrictions were particularly pronounced in the vertical plane. Next we analyzed the relevance of these impairments in the real-life scenario. As expected, PSP-patients showed significantly slower peak velocities and smaller amplitudes in the vertical plane. They also made substantially fewer voluntary saccades in the vertical plane. Some PSP-patients never showed saccades larger than 15 degrees and several were virtually unable to track a stationary target while walking. Performance in saccade peak velocity in the standard fixation protocol and the real-life scenario correlated significantly. Despite substantial inter-subject variability in PSP-patients, the fixation protocol did not only suffice to distinguish PSP from PD patients with a high sensitivity and specificity, but also predicted real-life performance.

Hence, our findings provide robust oculomotor markers to identify PSP from PD and demonstrate how these restrictions translate into the patients’ everyday lives. These data suggest that reflexive and voluntary eye movements assessed in freely moving patients provide a robust and efficient tool to differentiate PSP from other forms of Parkinsonism.


Spatial biases in viewing behaviour
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Viewing behavior is heavily constrained by stimulus content and task goals. However, such factors do not exhaust the causal mechanisms underneath ocular movements control since there is temporal and spatial structure in viewing behavior that seems to be independent of both stimulus and task. In this study we look into horizontal spatial biases in human viewing behavior. To avoid the confound between stimulus and behavioral bias, we compared between the exploration of images when presented in their original and mirror-reversed version. In experiment 1, right-handed subjects freely explored static complex scenes taken from different image categories (natural, urban, fractal and noise). We found a marked left bias at the start of exploration which was independent of image category and it was mostly explained by a bias in the first movement done in the image. This left bias was followed by a weak bias to the right that persisted until the end of the trial (6s). In experiment 2 we asked if these horizontal biases are related to handedness or could be explained by a differential hemispheric activation due to the images’ inhomogeneous spatial frequency distribution. A group of left- and right-handed subjects explored freely images presented in different spatial filtering versions (unfiltered, low-pass and high-pass). Images filtering did not change the bias pattern. In contrast, the group of left-handed subjects showed no left-bias at the beginning of exploration but neither a reversed bias. In experiment 3 and 4 we control the possibility that the described bias pattern could be a result of asymmetries in voluntary inhibitory control produced by the requirement to fixate in the middle before image presentation. In experiment 3, we introduced gaps of different duration between fixation control and image appearance resulting in no change in the bias pattern. Finally, in experiment 4 images appeared unexpectedly in a continuous succession without intermediary pause periods nor requirements to fixate previous image appearance. This arrangement also fail to change the bias pattern. In conclusion, we found a robust horizontal bias in the free-viewing behavior of right-handed subjects; this effect is independent of actual stimulus content or type, it is not explained but the spatial spectral characteristics of images nor by an asymmetry in inhibitory control.
Biased visual search in a homogenous background: no evidence of statistical learning

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To account for eye movement strategies during visual search, Najemnik and Geisler (2005; 2008) elaborated a Bayesian model that takes into account the retinal sensitivity when looking for a target in a background noise. At each fixation, their ideal searcher updates its representation about the target location to plan the next saccade so as to maximize the information collected. Their model describes human performance well.

We tested whether introducing a target location bias would affect the visual search strategies of participants naïve to the purpose of the study. An optimal observer would use such prior information to make the search more efficient.

We modified Najemnik and Geisler’s paradigm by presenting the target (a 6 cycles/deg sine-wave grating tilted 45° to the right) four times more often in one quadrant of a circular 1/f background noise (root-mean-squared contrast: 0.07). We tested different target visibilities (corresponding to d’ between four and one).

In general, the search efficiency during this biased search was high. Median fixation counts on correct trials varied from three to seven, median detection times from two to five seconds. However, there was no bias of saccade sequences toward the quadrant containing the target more often.

These results show that the participants did not use the probabilistic information about the target location to increase their performance. This is in contrast to recent studies observing statistical learning when subjects have to identify a target among four (Kabata & Matsumoto, 2012), eight (Jones & Kashak, 2012) or twelve (Jiang et al., 2013) distinct items. Presumably it is more difficult to induce statistical learning when the search target can appear at any position in a homogenous background.

Quantifying scanpath similarity in real-world data

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Recent advances in eye-tracking technology have begun to increase the amount of gaze allocation data of observers acting in real-world situations. This calls for novel quantitative tools for the efficient analysis of large amounts of eye-movement data. Here, we suggest a distance metric for estimating the similarity of scanpaths, “Median Minimum Distance”. We evaluate it on psychophysical data obtained on images from three databases commonly used in eye-tracking recordings. We find that clustering scanpaths based on Median Minimum Distance outperforms all other tested measures in terms of robustness and meaningfulness.

Programming of saccades to double-step targets in scene viewing: A test of assumptions present in the CRISP model

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In this study we utilized a double-step paradigm to investigate saccade programming within a naturalistic scene-viewing context. Several computational models explaining fixation durations in scene viewing (Nuthmann, Smith, Engbert, & Henderson, 2010) and in reading (Engbert, Nuthmann, Richter, & Kliegl, 2005; Reichle, Pollatsek, Fisher, & Rayner, 1998) assume that saccade programming is completed in two stages. Programming in the initial labile stage is subject to cancellation, while cancellation is no longer possible in the subsequent non-labile stage. This distinction is derived from classic double-step studies that utilised much simpler stimuli than is found in scene-viewing or reading experiments (Becker & Jürgens, 1979). In this study, we adapted the classic paradigm to the scene-viewing context to verify these modelling assumptions. Furthermore, performance in the Scene condition was directly compared to performance in a typical Static double-step condition. We found evidence in support of the claim that saccade cancellation does occur within a naturalistic scene-viewing context and that saccade cancellation can account for increased fixation durations. We provide estimates for the duration of the non-labile stage and demonstrate that it is longer in the Scene compared to Static condition.
Tracking eye movement while driving in underground tunnels

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Driving in the underground tunnels requires a heavier cognitive load than driving in an open environment. Previous Studies have found that drivers under greater cognitive load tend to have tunnel vision while driving. It thus suggests that their visual attention is primarily focus on the road ahead, oblivious to the peripherals, mirrors and instruments. To test this possibility in real situations for drivers and underground tunnels, we tested 15 drivers’ behavioral patterns and tracked their eye movements while they were driving in an underground tunnel express way (Kallang Paya Lebar Expressway, KPE) in Singapore. We found that most of the drivers focused their eye positions at the vehicles in front of them (same lane or the lane next to the driver's) and rarely looked at the mirrors when they were instructed to drive straight ahead. When instructed to change to the left or right lane, they looked at the mirrors and dashboard before and after the action. More often, they tend to sweep the tunnel ceiling near the ceiling lights and the boundaries of the lane in front of them. At curves, they tend to look at the wall of the tunnel (at the inner side of the curve) with reflective materials and thus brighter than the other areas. Since we simply instructed the subjects to drive ahead, this freely eye movement pattern may reflect the key elements for saliency of the scene in underground tunnel environment – motion and illumination.
**LIST OF PARTICIPANTS**

**ZiF RESEARCH GROUP: COMPETITION AND PRIORITY CONTROL IN MIND AND BRAIN: NEW PERSPECTIVES FROM TASK-DRIVEN VISION**

**Workshop: Eye Tracking Methods and Scan Path Analysis**

Convenors: Wolfgang Eínhäuser-Treyer (Marburg, GER) and Kenneth Holmquist (Lund, SWE)

**March 6 - 7, 2013**

Stand 26.2.2013

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