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Preface

The *Tübinger Wahrnehmungskonferenz* is celebrating its 10th anniversary. We are proud to see TWK becoming an established tradition while extending its scope over the past decade. We would like to thank all the participants who have helped to make this conference a success. We are especially grateful for all the support received by the numerous local helpers.

This year's symposia are deliberately chosen to focus on developmental, behavioural, and even social aspects of perception and cognition. This reflects the dynamic changes in TWK since the very beginning. TWK was anticipated to become a conference with a "cognitive-science view on perception," and is currently bridging perception and cognition as never before. For the future we seek to maintain TWK's interdisciplinary nature and also encourage submissions addressing higher-level cognitive functions.

Ever since the third TWK in 2000 we have awarded the best poster contributed by an undergraduate or graduate student. In 2006 the poster prize was awarded to Jutta Billino of the University of Giessen for her contribution, "Age-related differences in motion tasks of different complexity". The prize of a cheque for 500 Euros will again be awarded at this TWK and is donated by the *Förderverein für neurowissenschaftliche Forschung e.V.*, whose support we gratefully acknowledge.

The Organizing Committee
Tübingen, July 2007

Sponsoring Institutions

Max-Planck-Institut für biologische Kybernetik, Tübingen, Germany
Eberhard-Karls-Universität Tübingen, Germany
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Vorwort
von Prof. Dr. Bernd Engler und Dr. Niels Weidtmann

Sehr geehrte Teilnehmerinnen und Teilnehmer,

ich freue mich, Sie anlässlich der 10. Tübinger Wahrnehmungskonferenz recht herzlich an der Eberhard Karls Universität Tübingen willkommen heißen zu dürfen. Die Tübinger Wahrnehmungskonferenz erfreut sich in diesem Jahr wieder des ungebrochenen Interesses zahlreicher Wissenschaftlerinnen und Wissenschaftlern verschiedenster Fachdisziplinen aus der ganzen Welt. So bringt die Konferenz Forscherinnen und Forscher der Bereiche Biologie, Psychologie, Medizin und Informatik zusammen, um aktuellste Fragestellungen rund um das Thema Wahrnehmung intensiv zu diskutieren. Ich freue mich daher sehr, dass sich das nunmehr 10 Jahre alte Konzept der Konferenz, trotz einiger kleiner Wandlungen, bewährt hat und es gelungen ist, seit der ersten Ausrichtung der Konferenz im Jahre 1998 immer mehr Teilnehmer, insbesondere auch aus dem Ausland zu gewinnen. Gerade der internationale, fächerübergreifende Dialog ist für den wissenschaftlichen Fortschritt von sehr großer Bedeutung. Heute zählt die Tübinger Wahrnehmungskonferenz mit einer durchschnittlichen Teilnehmerzahl von 250 Personen mit zu den größten internationalen Konferenzen ihrer Art in Deutschland. Anlässlich des zehnjährigen Jubiläums umfassen die verschiedenen Symposien in diesem Jahr zum ersten Mal einen übergreifenden Themenschwerpunkt. Zudem bietet die Konferenz eine umfangreiche Postersitzung und bindet auch das wissenschaftlich interessierte Publikum außerhalb der Konferenzteilnehmer im Rahmen eines öffentlichen Abendvortrags mit ein, was ich sehr begrüße.

Ich wünsche allen Teilnehmerinnen und Teilnehmern einen guten Verlauf der Konferenz, interessante Vorträge und Diskussionen sowie gewinnbringende persönliche Begegnungen. Mein Dank gilt allen beteiligten Kolleginnen und Kollegen des Max-Planck-Instituts für Biologische Kybernetik und der Eberhard Karls Universität Tübingen, die sich bereits seit zehn Jahren in einer sehr bewährten Zusammenarbeit für die Ausrichtung dieser Veranstaltung engagieren.

Professor Dr. Bernd Engler
Rektor der Eberhard-Karls-Universität Tübingen

Zum zehnten Mal kommen in Tübingen Wissenschaftler aus aller Welt zusammen, um gemeinsam über Wahrnehmung und ihre neuronale Verarbeitung nachzudenken. Von der ersten Konferenz im Jahr 1998 an stand das Treffen im Zeichen eines fächerübergreifenden Austausches: Psychologie, Biologie, Medizin und Informatik liefern sich gegenseitig wichtige Impulse bei der Erforschung der Wahrnehmungsverarbeitung und der Integration von Wahrnehmungen in komplexere kognitive Prozesse wie Orientierung, Lernen, Handeln, Sprechen, Erinnern und Gedächtnis und viele mehr. Dass sich in diesem Schnittfeld die Kognitionswissenschaft gebildet hat, die versucht, die Erkenntnisse der verschiedenen Wissenschaften aufzunehmen und zu einem größeren Bild zu verknüpfen, zeigt, wie erfolgreich die Zusammenarbeit über Fächer- und Disziplinengrenzen hinweg ist. Der Forschungsgegenstand fordert und fördert Allianzen zwischen Disziplinen ganz verschiedener Fächer. Diese einfache Wahrheit wird auf der Tübinger Wahrnehmungskonferenz konsequent umgesetzt.

Dass die Veranstalter Kognition zum übergreifenden Themenschwerpunkt aller drei Symposien der diesjährigen Konferenz gemacht haben, mag auch daran liegen, dass Wahrnehmung längst nicht mehr als Einbahnstraße verstanden wird. Kognitive Prozesse beeinflussen ihrerseits Wahrnehmungen, und folgerichtig wird auch die (visuelle) Wahrnehmung selber als ein kognitiver Prozess betrachtet, der nicht isoliert verstanden werden kann. Kognition und Wahrnehmung sind dabei wesentlich bestimmt durch die Einbettung in die Körperlichkeit menschlicher Existenz. Das komplexe Zusammenspiel von geistigen Prozessen, Körper und Umwelt weiter aufzuklären, ist ein Punkt, an dem auch Vertreter anderer Wissenschaften aufmerksam werden und den auf der Tübinger Konferenz vortragenden Disziplinen sehr genau zuhören werden, geht es doch an dieser Stelle um den ganzen Menschen in seinen vielfältigen Bezügen.

Die Veranstalter sind dafür zu beglückwünschen, dass sie mit ihrer Konferenz solch sachorientierten interdisziplinären Austausch fördern. Das FORUM SCIENTIARUM, das sich auf breiter inhaltlicher Ebene dem Dialog zwischen den Wissenschaften widmet und diesen auch in die Lehre zu tragen versucht, verfolgt die Tübinger Wahrnehmungskonferenz deshalb mit besonders großem Interesse.

Dr. Niels Weidtmann
FORUM SCIENTIARUM Tübingen

Friday 27th July 2007

14:00 Registration and hanging of posters

14:55 Welcome

Symposium 1: Spatial Cognition—the Active Observer in Real and Simulated Spaces (Jenny Campos and Betty Mohler, MPI for Biological Cybernetics, Tübingen)
Symposium to be conducted in English

15:00 **Introduction**
Betty Mohler & Jenny Campos (MPI for Biological Cybernetics, Tübingen)

15:10 **Seeing Big Things in Real, Virtual, and Desktop Environments**
Dennis Proffitt (University of Virginia)

15:40 **Embedded and Embodied Cognition in Real-World Environments**
Mark May (Universität der Bundeswehr, Hamburg)

16:10 Coffee break

16:40 **Investigating Multi-Sensory Integration in the Estimation of Distance Traveled**
Jenny L. Campos (MPI for Biological Cybernetics, Tübingen)

17:10 **Path Integration in Real and Virtual Environments: Mechanisms and Strategies**
Jan Wiener (Collège de France, Paris)

17:40 **It's What You Feel That's Important, Not What You See.**
Roy Ruddle (University of Leeds, UK)

Saturday 28th July 2007

Symposium 2: Development of Perception and Cognition
(Sabina Pauen, University of Heidelberg)
Symposium to be conducted in English

09:00 **The More You Give the More You Get: How Infants Identify Category Membership**
Diana Sodtke (University of Magdeburg), Birgit Traeuble (University of Heidelberg) & Sabina Pauen (University of Heidelberg)

09:30 **Neural Evidence for Intermodal Perception in Emerging Object Representations**
Lysett Babocsai (University of Heidelberg), Sabina Pauen (University of Heidelberg) & Manuela Friedrich (MPI for Human Cognitive and Brain Sciences, Leipzig)

10:00 **The Development of Eye Gaze Perception in Triadic Interactions in Infancy**
Stefanie Hoehl (MPI for Human Cognitive and Brain Sciences, Leipzig) & Tricia Striano (Neurocognition and Development Group, University of Leipzig)

10:30 Coffee break

11:00 **Infants' and Adults' Fixation Patterns When Encoding Intentional Actions**
Annina Neumann, Claudia Thoermer & Beate Sodian (Ludwig-Maximilians-Universität München)

11:30 **Gaze Perception Helps Infants to Infer Category Preferences**
Sabina Pauen (University of Heidelberg)

12:00 **The Development of Early Action Perception and the Relation Between Early Action Perception and Action Planning**
Bianca Jovanovic (University of Giessen)

12:35 Lunch break

Poster sessions
The posters will be divided into 4 groups. The authors should be present at their poster at least during the time allocated to their group as follows. The poster boards will be marked to indicate which group the poster is in. Note that we have extended the poster session to allow more time at the posters.

13:45 Group A

14:55 Group B

16:05 Group C

17:15 Group D

18:20 Poster prize to be awarded

Public evening lecture (to be given in German)

18:30 **Töne sehen - Über Synästhesie und sensorische Substitution**
Petra Stoerig (Universität Düsseldorf)

20:15 Banquet in the Casino am Neckar

Sunday 29th July 2007

Symposium 3: Social Nature of Perception and Action
(Guenther Knoblich, Rutgers University)
Symposium to be conducted in English

10:00 **Introduction**
Günther Knoblich (Rutgers University, US)

10:10 **On the Human Body: Between the Self and the World**
Manos Tsakiris (University College London, UK)

10:40 **Understanding Goals and Actions in the Brain**
Antonia Hamilton (Dartmouth College, US)

11:10 Coffee break

11:40 **From Action Perception to Joint Action**
Natalie Sebanz (Rutgers University, US)

12:10 **The Motor Foundations of Social Perception**
Patric Bach & Steve Tipper (University of Wales, Bangor, UK)

12:40 **Eye and Thou**
Daniel Richardson (University of California, Santa Cruz, US)

13:10 Closing discussion, removal of posters, end of conference

Contents

Public evening lecture (to be given in German)

Prof. Dr. Petra Stoerig
Heinrich-Heine-Universität Düsseldorf

28.07.07

Töne sehen: Über Synaesthesie und sensorische Substitution

Petra Stoerig

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Wenn jemand eine Stimme als „schön, rau und veilchenfarben“ beschreibt und ein anderer dieselbe Stimme entschieden als „zartgrün“ beschreibt, dann handelt es sich mit großer Sicherheit um ein Gespräch zwischen zwei Synaestheten. Im Unterschied zu den viel häufigeren Nicht-Synaestheten, die Schall nur hören und Lichtreize nur sehen, haben Synaestheten zusätzliche Sinnesempfindungen, nehmen zum Beispiel ganz spezifische Farben, Formen oder Texturen wahr, wenn sie Töne, Wörter oder Musik hören. Synaesthetische Kopplungen entstehen oft in der Kindheit, so dass sich die Betroffenen nicht erinnern können, jemals anders gehört, gesehen, gefühlt zu haben. Synaesthesien können aber auch durch sensorische Deprivation verursacht werden, so dass etwa erblindete Menschen die über ihre intakten Sinneskanäle vermittelten Informationen häufiger als Sehende mit zusätzlichen visuellen Qualitäten versehen.

Sensorische Substitution des Sehens versucht, den Blinden die nicht länger verfügbare visuelle Information wieder zugänglich zu machen, indem sie sie in ein Format übersetzt, das ein intakter Sinn auslesen kann. Substitutionssysteme konvertieren dazu die Bilder einer Videokamera in taktile oder auditive Muster, um lautlose, außerhalb des Greifraums befindliche Objekte wieder wahrnehmbar zu machen. Wie erfolgreich sensorische Substitution sein kann hängt in erster Linie davon ab, inwieweit die Betroffenen die durch die Konvertierung entstehenden Berührungs- oder Geräuschmuster verstehen lernen. Bisher wurde in einer Reihe von Studien gezeigt, dass sich blinde und verblindete Personen durch Substitutionstraining verbessern, wobei üblicherweise vergleichsweise einfache Sehreize verwendet werden. Ob die Substitutionssysteme den Blinden das Erkennen realer Gegenstände und Szenen ermöglichen können, ob die Sehrindengebiete, die ihre Eingangssignale von der Netzhaut verloren haben, die Analyse der konvertierten visuellen Information übernehmen und ob durch längere Nutzung solcher System synthetische Synaesthesien entstehen können, ist bislang kaum untersucht worden.

Unterstützt durch die Volkswagenstiftung (I/80 742)

Symposium 1

Spatial Cognition—the Active Observer in Real and Simulated Spaces

Jenny Campos and Betty Mohler
MPI for Biological Cybernetics, Tübingen

Seeing Big Things in Real, Virtual, and Desktop Environments

Dennis Proffitt

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That vertical extents are perceived as being greater than equivalent horizontal ones is a well-known pictorial illusion. In a number of studies, we have found that the magnitude of this illusion is much bigger when viewing objects in the real world as opposed to small depictions; moreover, the magnitude of the illusion is correlated with object size. For example, the vertical extent of a tall building is perceived to be exaggerated more than that of a mailbox. The vertical / horizontal illusion that is found outdoors has a similar magnitude in virtual environments (VEs) viewed with head-mounted displays, but the illusion is greatly reduced when the same VE's are presented on small flat displays. This difference between immersive and small flat displays is found even when the visual angles of the displayed objects are equated. When creating small displays depicting big objects, vertical extents need to be exaggerated if the goal is to evoke a perception of the objects' "real-life appearance." Artists, such as Monet, knew this and exaggerated the vertical extents of the largest buildings in their paintings.

Embedded and Embodied Cognition in Real-World Environments

Mark May

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Recent research on spatial perception and memory in real-world environments illustrates some of the nontrivial consequences of an embedded and embodied view on cognition. In a typical experiment blindfolded volunteers have to remember and point to objects from different real or imagined perspectives in their actual or a remote surrounding. Central findings are: (a) When observers are asked to imagine a perspective different from the one bodily taken, pointing latencies and errors increase as a function of the spatial disparity between real and imagined perspective. (b) When they are allowed to bodily switch into a new perspective, pointing performances are comparable to baseline conditions without perspective switch. (c) When observers are systematically disoriented relative to the surrounding detrimental effects of imaginal switches are significantly reduced. (d) Beneficial effects of bodily switches and detrimental effects of imaginal switches are stronger when people are tested in the actual as compared to a remote room environment. These and other findings call for an approach to spatial cognition that accounts for complex interactions between mind/brain, body, and environment.

Investigating Multi-Sensory Integration in the Estimation of Distance Traveled

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Traversed distance perception involves estimating the extent of self-motion as one travels from one position in space to another. It is a multi-modal experience in which information from both visual flow and locomotor cues (i.e. proprioceptive, efference copy and vestibular cues) jointly specify the magnitude of self-motion. While recent evidence has demonstrated the extent to which each of these cues can be used independently to estimate traversed distance, relatively little is known about how they are integrated when simultaneously present. Here, a series of studies conducted in both virtual and real-world environments show that humans use a combination of visual flow and locomotor cues to estimate distance traveled. During walking the presence of visual flow results in a relative underestimation of distance traveled compared to circumstances in which it is absent (blindfolded walking). When visual gain is manipulated during walking, thus causing an incongruency between the two cues, locomotor cues appear to be weighted higher overall. This is true in environments consisting of a rich visual scene (real world) and those in which visual flow is isolated (VR).

Path Integration in Real and Virtual Environments: Mechanisms and Strategies

Jan Wiener

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Path integration, the ability to sense and integrate self-motion for keeping track of orientation and position changes, constitutes a fundamental mechanism of spatial navigation and plays a key role in the development of cognitive maps. Here two experiments in real and virtual environments are presented that studied the mechanisms underlying human path integration. By systematically varying the complexity of the traveled path in Experiment 1, and by explicitly instructing participants to use different updating strategies in Experiment 2, two alternative processing modes for updating the start location of a journey were identified and compared. The first mode is in line with existing models of human path integration (Fujita et al., 1993), assuming that the traveled path is remembered and a homing vector, i.e. an ego-centric representation of the start position of the travel, is computed upon a survey representation only if required. The second mode constitutes a continuous updating process as described for many animal species. In the continuous mode a home-vector is available at all times during navigation. The experiments demonstrate that participants could employ both path integration modes (Experiment 2) and that they deliberately switched between modes according to the complexity of the traveled path (Experiment 1).

It's What You Feel That's Important, Not What You See.

Roy Ruddle

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During navigation, humans combine visual information from their surroundings with body-based information from the translational and rotational components of movement. Referring to studies of navigational search, I will show that efficient navigation requires full (translational and rotational) body-based information, but only moderate visual detail. This challenges assumptions about the preeminence of visual landmarks in spatial learning, and questions how much tasks such as path integration inform our understanding of the complex spatial tasks we perform in everyday life. At a theoretical level I will conclude with questions about the role of spatial extent and each aspect of body-based information, and at the applied level I will explain how virtual reality interfaces should be optimised for applications such as ergonomic design.

Symposium 2

Development of Perception and Cognition

Sabina Pauen
University of Heidelberg

The More You Give the More You Get: How Infants Identify Category Membership

Diana Sodtke,[1] Birgit Traeuble[2] and Sabina Pauen[2]

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Previous research has shown that 11-month-old infants distinguish animals from furniture in an object manipulation task (e.g. Mandler & McDonough, 1998). In this kind of task, infants are first familiarized with four different exemplars of one category (either animals or furniture), followed by one new exemplar from the familiar category and one new exemplar from the contrasting category at test. Pauen (2002) demonstrated that infants discriminate both categories equally well when perceptual between-category similarity is artificially increased: In one condition, the author presented plastic toy stimuli and wooden furniture items that were highly naturalistic looking miniature models of real-world exemplars. In a second condition, the same exemplars were represented by abstract wooden figures. To increase between-category similarity, all animals and furniture items showed rectangular as well as rounded edges, and all items had eye-like markings. In addition, each furniture exemplar had a similar overall-form as one animal, was painted in the colours of another animal and revealed the same pattern as a third animal-exemplar. Despite these manipulations, 11-month-olds participating in both conditions showed almost identical performance. Based on this observation, it was concluded that infants use perceptual information to identify category membership rather than forming the category on-line. This raises the question what type of information allows infants to identify the given toys as either animals or furniture. The present study examines this issue, comparing performance in three conditions varying kind and amount of perceptual information given: (a) Form plus eye-like markings: All objects (animals and furniture exemplars) were painted in the same colour, without any pattern information. (b) Form plus eye-like markings plus pattern information. (c) Form plus pattern and colour information, but without eye-like markings. Analysis of looking-time revealed that with every single perceptual cue added, looking time increased during the test phase, but did not increase significantly when the category change was introduced. However, when examination-time served as dependent measure (a part of looking time with increased attention, lower heart-rate and more cognitive processing), all three conditions (a-c) lead to equal responding. In contrast to the original study (all information given), no categorization could be observed. Based on this pattern of findings we conclude that a certain threshold of perceptual information is needed to allow category identification, while amount of visual attention is primarily determined by the complexity of the given stimuli.

Neural Evidence for Intermodal Perception in Emerging Object Representations

Lysett Babocsai,[1] Sabina Pauen[1] and Manuela Friedrich[2]

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Acquisition of semantic knowledge about objects requires the integration of diverse sensations into a unified percept. Behavioral studies on intermodal integration have showen that this ability is already present in early infancy. However, studies that focus on the relation between sight and sound in infants' emerging semantic object representation are still rare. Research concerning lexical-semantic representations provides evidence that the ability to establish relations between meaningful words and picture contents is present in the second year of life. Friedrich & Friederici (2005) applied the method of event-related brain potentials and demonstrated that 19 but not 12 month-old children reveal semantic integration as indexed by the N400 in response to words that were incompatible with the picture contexts. The present study applies the same experimental paradigm but focuses on infants' auditory-visual coordination of pictures and natural sounds. A total of 46 infants participated. Each infant received up to 120 sequentially presented picture-sound pairs. Pictures of animals and inanimate objects were shown for 2000 msec before a natural sound started to play for 1500 msec. Pictures remained visible during this time and continued to be in sight for another 500 msec after the sound terminated. The sounds were either congruous or incongruous to the picture content. Data analyses based on 30 infants who met the criterion of 20 artifact-free trials per condition revealed that 12-month-old infants display a more negative response to congruous sounds than incongruous sounds over fronto-lateral brain regions starting around 200 msec after sound onset. This early semantic priming effect might originate from the influence of the picture context leading to the expectation of a semantic element consistent with the visual representation. Additionally, sounds incongruous to the picture content elicited a greater N400 response compared to congruous sounds over anterior brain regions. This effect reflects mechanisms of semantic integration that are elicited in response to incongruous sounds in 12-month-olds even though they are not yet present in response to incongruous words at that age. These findings suggest that infants as young as 12 months have object representations that combine visual and acoustic information thus providing neurophysiological evidence for the early integration of semantic knowledge from different sensory modalities within global categories.

The Development of Eye Gaze Perception in Triadic Interactions in Infancy

Stefanie Hoehl[1] and Tricia Striano[2]

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By 4 months of age infants use the eye gaze of adults to guide their attention and facilitate processing of environmental information [1]. In a series of event related potential (ERP) studies we addressed the question of how infants' processing of another person's eye gaze toward or away from an external object develops within the first postnatal year. We applied a visual ERP paradigm with 2-, 4-, 6- and 9-month-old infants. Infants were presented portrait pictures of actors directing eye gaze either toward or away from small colorful objects next to their faces, while EEG was continuously measured. At the age of 2 months infants displayed a well-known mid-latency negative component (Nc) on fronto-central channels. This component has been related to attentional processes in previous studies [2]. However no difference was found in amplitude or latency of this component in this age group. At the age of 4 month infants showed differential processing of object-directed vs. non-object-directed eye gaze. The Nc was significantly enhanced in amplitude and larger in latency when eye gaze was directed away from the object, indicating enhanced attentional arousal in this condition. Presumably the non-object-directed eye gaze was less expected by the 4-month-old infants and therefore attracted more attention. This indicates that young infants already have expectations about the directedness of human eye gaze that might be similar to those of adults. A similar pattern was found in 6-month-old infants' neural responses that also showed enhanced amplitude of the Nc in the non-object-directed gaze condition. The 9-month-old infants' data that was acquired using the same paradigm as described above was contaminated strongly by eye movements of the participating infants. One explanation could be that our stimuli, though suiting infants at younger ages, were too monotonous for the older infants, who did not attend to the pictures long enough to acquire data of sufficient quality. A second interpretation is that at 9 months infants more often actively followed the actors' eye gaze than at younger ages, thus causing severe artifacts in the EEG data. Behavioral analyses of infants' gaze shifts confirm that 9-month-olds performed shifts three times as often as infants in younger age groups. The implications of these findings for the development of joint attention and related social cognitive functions will be discussed.

[1] Reid and Striano (2005): Eur J Neurosci
[2] de Haan, Johnson, and Halit (2003): Int J Psychophys

Infants' and Adults' Fixation Patterns When Encoding Intentional Actions

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Looking time paradigms have been widely used in developmental research when investigating the visual and cognitive abilities of preverbal infants. An important shortcoming of this method lies in its reliance on the pure amount of an infant's overall looking time at the often complex stimulus configuration. It does not allow an analysis of the particular aspects of the stimulus configuration that infants attend to. Yet, this information can be crucial in correctly interpreting the infant's encoding and processing of the presented stimuli or events. This talk will focus on how additional eye-movement analysis can be used to clarify infants' encoding strategies that underlie looking times. Specifically, a series of studies analysing infants' and adults' encoding of action roles in a social exchange situation will be discussed. In these studies a detailed Markov chain analysis of fixation patterns was used to identify and relate different encoding strategies. Data suggested that infants who successfully encoded action roles were able to link action to person identity, whereas infants failing to identify action roles used strategies based on irrelevant spatial parameters. Further, it will be shown how infants' encoding competencies still differed from adult encoding and why this finding could not have been deduced from the analysis of overall looking times alone.

Gaze Perception Helps Infants to Infer Category Preferences

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During their first year of life infants come to understand that specific objects can be the target of a given person's action (Woodward, 1998; Thoermer & Sodian, 2001). Studies on object categorization further reveal that same-aged infants are well able to categorize objects at the global level (e.g. animals and vehicles; see Mandler & McDonough, 1993). The present study combines both lines of research for the first time, asking whether 12-month-olds understand that objects of a given global category (rather than one specific exemplar) can be the target of interest of a human actor. Two groups of N = 22 12-month-olds each (sex balanced) watched a sequence of 10 familiarization scenes and one test scene, lasting 18 seconds each. Each scene started with a screen shot of two new objects (an animal and a vehicle), positioned in the left and the right half of the display. Next, infants saw either a woman (person condition) or a desk lamp (object condition), placed in a central position in between both objects, facing the child. In the person condition, the woman turned her head towards one of the two targets with a facial expression of high interest. In the object condition, the desk lamp turned towards the target and fleshed it. During 10 familiarization trials, the person / lamp always turned to a new object of the same kind category (left-right position counterbalanced), but on trial 11 (test), she / it turned to the object of the contrasting category. Half of the infants in each group received animals, and the other half received vehicles as familiarization stimuli. Two independent coders measured infants' looking time on each trial (r = .97). Means of both coders for each trial served as dependent measure. During the familiarization phase, mean looking time decreased from the first to the second five trials, $F(1,36)=16.41$, $p<.001$. This effect was independent of condition (person, lamp), $F(1,36)=1.60$, $p=.22$, and target category (animals, vehicles), $F(1,36)=0.50$, $p=.49$. At test, a significant interaction between Trial (Fam10, test) and Condition (person, lamp), $F(1,36)=12.64$, $p=.001$, was observed. This interaction was qualified by an increase in looking duration in the person condition, $F(1,18)=11.04$, $p<.01$, and a marginally significant decrease in the lamp condition, $F(1,18)=3.69$, $p=.07$. Based on this finding, we conclude that 12-month-olds use gaze information to infer whether a given person is interested in a specifc class of objects, thus suggesting that similarity comparisons in visual perception can be influenced by social cues even at a preverbal age.

The Development of Early Action Perception and the Relation Between Early Action Perception and Action Planning

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The development of the ability to interpret central aspects of human action, and the relation of this ability to own action planning, have been in the focus of recent research in early cognitive development. The most basic aspect of an action, distinguishing an action from a mere movement, is its goal-directedness, mirrored by the fact that an action is usually directed at producing some intended end-state, such as when grasping an object. The ability to represent simple instrumental actions as goal-directed is indeed one of the first aspects of action perception to develop, with a corresponding rudimentary capacity appearing as early as 6 months of age. At the same time, simple movement-effect units can be regarded as the lowest level of ultimately hierarchical, complex action representations that develop significantly later. The present contribution focuses on two aspects. First, it outlines the development of the understanding of manual actions starting from an understanding of simple actions to the ability to parse more complex action sequences into meaningful chunks. Here, special attention is given to the influence of action effects on the perception of actions at different levels of complexity and to the question of what represents a "meaningful" action at different ages. The second aspect refers to the planning of goal-directed actions. Specifically, the development of anticipatory task adaptation and planning efficiency will be addressed, as well as the question of whether and to which extent differences between the efficiency of own action planning and the perception of the efficiency of another person's performance on the same task exist.

Symposium 3

Social Nature of Perception and Action

Guenther Knoblich
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On the Human Body: Between the Self and the World

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We constantly feel, see and move our body, and have no doubt that it is our own. Correct demarcation of the physical body's boundaries seems to be essential for goal-directed action, for our sense of who we are and for our successful interaction with other agents. In every inter-action, there are both private and public states and signals represented in the brain of the agent and the observer. Private signals refer to centrally generated action representations such as intentions, efferent signals (e.g. efference copy, motor commands), and re-afferent signals such as proprioception. Public signals originate from observable sensory events, both re-afferent and ex-afferent, such as visual and auditory signals that may refer to bodies, objects or complex patterns of motor behaviour. How are these signals used to disambiguate the identity of bodies and the origin of actions? A series of experiments showed that ownership of one's body is based on the integration of multisensory signals such as touch, vision and proprioception. However, body-ownership is modulated by other factors which imply an internal representation of the body, over and above current bodily sensation. First, representations of the anatomical and functional structure of the body (e.g. morphological characteristics, body-part identity and posture) modulate body-awareness by providing the background conditions against which new multisensory percepts are assimilated. In addition, motor signals provide a coherent representation of the body's several parts, by structuring bodily sensations across time and space. Importantly, the experience of one's action may function as a unifying element that structures a coherent representation of the body, as distinct from the world. Taken together, these results may explain the ways in which percepts of action and bodily effects can be experienced so clearly and inexorably as being "mine", and not yours.

Understanding Goals and Actions in the Brain

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When a father sees a child reach towards a cookie jar, he knows immediately what the child wants. My research investigates the neural and cognitive systems which underlie the ability to understand other people's goal directed actions. This ability is essential to many simple social interactions, such as when the parent takes the cookie from the jar to give to the child. Goal understanding may also enable more complex social skills such as understanding other people's desires and beliefs. I will present recent neuroimaging results demonstrating that the goals and outcomes of other people's actions are encoded in parietal regions of the brain, while simpler kinematic motion patterns are encoded in visual and inferior frontal regions. These results can best be understood in terms of an emerging hierarchical model of action understanding, which maps onto the hierarchical brain systems for the control of one's own complex actions. Under this framework, understanding action is not just a matter of 'direct matching' in a mirror neuron system, but requires a more sophisticated process with many different levels of representation. Recently, several papers have emerged suggesting that disruption these matching processes in the mirror neuron system could be a cause of autism. I will present behavioural data demonstrating that children with autism have normal goal understanding abilities, and that a mirror neuron system explanation of social disability in autism is not plausible. More advanced models of action and goal understanding are required to make sense of social cognition in the typical and the autistic brain.

From Action Perception to Joint Action

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Humans engage in a wide range of social activities that require predicting what others are going to do next. Previous research has focused on the role of higher cognitive functions, such as the ability to infer others' mental states and the use of language, in social exchange. In this talk, I will present recent studies suggesting that a close link between action observation and action execution also provides a mechanism for predicting others' actions. First, I will present new behavioral and fMRI data showing that by mapping perceived actions onto their own repertoire, individuals can predict the outcome of others' actions and infer their intentions based on action observation. Second, I will present studies suggesting that individuals have a tendency to represent others' tasks, which allows them to make predictions about others' actions in the absence of observable action cues. I will discuss how these processes contribute to joint action, and how they relate to theory of mind.

The Motor Foundations of Social Perception

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It has been proposed that humans represent knowledge about others with their own action system. This allows two predictions: First, knowledge about other people should have an immediate effect on the observers' own actions. Conversely, the actions of the observer should affect how he perceives other persons. Two new effects provide evidence for both predictions. First, simply identifying the faces of well-known athletes affects the action system of the observer, such that responses are more fluent—faster and more accurate—depending on their similarity to the motor skills of the athletes. Thus, knowledge about the motor skills of others directly affects the observers' own actions. Second, the reverse effect can also be demonstrated. The fluency of the observer's own motor responses can become misattributed to the actions of observed persons, affecting subsequent decisions about their personality and skills. Thus, even our initial judgments about others depend on the actions we perform at the same time. Both effects demonstrate the tight coupling between sensorimotor processes and the representation of social knowledge. They occur even though the actions or motor skills of the observed persons are completely task irrelevant. This indicates a high automaticity of the sensorimotor processes involved in social judgments.

Eye and Thou

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Movements of the eye are determined by an interaction of low level properties of the stimulus and high level cognitive factors. Typically in eye movement research, the cognitive factors are that are investigated are expectations or schemas for particular types of scene. I will present three studies demonstrating that social factors also have a substantial contribution to eye movements. In the first, participants watched a video of people giving their views on a sensitive political issue. One speaker made a potentially offensive remark. If participants believed these remarks could be heard by others, they fixated individuals who were likely to be offended. In a second study, two participants in adjacent cubicles had a discussion over an intercom while they were eye tracked. We found that their gaze coordination was modulated by what each believed the other could see on the computer screen. In the final study, we simply showed sets of four stimuli to pairs of participants. We found that that individuals looked at photographs differently if they believed that the other person was looking at the same images, or a set of random symbols. Together these experiments demonstrate that social forces have a strong effect on perceptual mechanisms. Gaze patterns are determined by what we think others will feel, what we think our conversation partners can see, and simply whether or not we think we are looking alone or with other people.

Attention and Awareness

Temporal Preparation Improves Temporal Resolution

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If a warning signal announces the moment at which an imperative response signal occurs, one can temporally prepare for that moment and thus respond especially fast. In addition, recent research shows that temporal preparation improves the spatial resolution of the visual system. The present experiments were designed to investigate if similar benefits of temporal preparation can be observed in a task which requires a high temporal instead of a high spatial resolution. To this end, we conducted two experiments to investigate the effect of temporal preparation on performance in a temporal order judgment task. Temporal preparation was manipulated in a constant foreperiod design, in which the time between a warning signal and a subsequent response signal (i.e. foreperiod) is kept constant across trials and varies between blocks of trials. In Experiment I, short foreperiods, which are known to yield better temporal preparation, facilitated temporal order judgments for two spatially adjacent dots. This finding was replicated in Experiment II, in which the temporal order of two spatially overlapping stimuli ('+' vs. 'x') had to be discriminated. Thus, these findings show that temporal preparation improves the temporal resolution of the visual system.

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Spatio-Temporal Grouping in Perceptual Rivalry

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Perceptual rivalry occurs when stimuli have multiple interpretations which are equally probable. For example, two distributions of dots, one translating leftward and one rightward can be perceived as a 3D-cylinder rotating clockwise or counterclockwise. Repetitive presentation of the ambiguous stimulus can stabilize one perceptual interpretation. Here we examined how unambiguous spatio-temporal contexts affected stabilization of ambiguous structure-from-motion stimuli. Using an intermittent presentation paradigm we stabilized one interpretation of the ambiguous cylinder and introduced contextual information by providing an unambiguous version of the 3D-cylinder. We manipulated spatial distance and temporal proximity between ambiguous stimulus and unambiguous context. The task was to report perceived rotation direction of the ambiguous cylinder. We found that stabilization was more likely to be disrupted by unambiguous context that had appeared in corresponding locations in preceding frames. Context simultaneously presented with the stimulus at a different spatial location had little effect. This shows that temporal contexts were weighted more than spatial contexts, and suggest that the visual system analyses recent perceptual history to interpret the present input.

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Lapses of Attention in Reaction Time Tasks Predict People's Beliefs about Their Everyday Life Attention and Memory

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In the past years, investigators have developed questionaires to assess people's beliefs about their attention and memory performance in natural circumstances. These questionaires have been used in many recent studies of everyday attention and memory phenomena. However, research has found that responses to these questionaires are reliable but do not (or only moderately) correspond with individual's performance in many classical reaction time (RT) paradigms. Lack of correspondence has been reported for a variety of chronometric tasks developed to assess aspects of selective, divided and sustained attention. In this study, we examined properties of subjective self-ratings, assessed with the Cognitive Failures Questionaire (CFQ, Broadbent et al., 1982) and their relation to serial RT performance, taken from a sample of 96 normal individuals. To obtain information beyond those observed with mean RT, we carried out a detailed investigation of the RT distribution. We examined RT variability and the frequency of attentional lapses, which we related to individual's self-ratings of everyday attention and memory. Consistent with the literature, self-ratings correlated only poorly with mean RT; however, we found positive correlations with RT variability as well as with the frequency of attentional lapses. Individuals who reported poor everyday attention showed a substantially larger number of abnormally slow responses, which was reflected in the skew of the RT distribution as well as in RT variability, but not (or to a lesser degree) in mean RT. In conclusion, the results demonstrate that fluctuations in attentional allocation in serial RT tasks correspond very well with individual's self-reported everyday attention and memory performance. Our findings revealed some important validity aspects which may be used for the evaluation of questionaires as a tool for studying attention and memory in the field.

Is Binocular Rivalry Influenced by Varying Moods?

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Binocular rivalry occurs when a different stimulus is presented to either eye. The percept alternates between the monocular images every few seconds. According to a study from Pettigrew [1] the perceptual alternation rate can be influenced by the indication of laughter: Pettigrew told his participants jokes to amuse them and found that laughter stopped the rivalry alternations between horizontal and vertical gratings and increased the occurrence of mixed percepts instead. He could preclude that simply shaking while laughing had this effect on binocular rivalry and suggested that mirth is sufficient for it. In the present study, we wanted to investigate the influence of different moods (cheering, glum, neutral) on the perceptual alternations during binocular rivalry. We provoked cheering, glum and neutral moods with video clips. Each clip was followed by a three-minutes period of rivalry stimulation. To induce binocular rivalry we dichoptically presented Gabor patches slanted orthogonally to the left or the right. The task of the participants was to press the one of two buttons assigned to the slant of the perceived grating. To control for our success in provoking varying moods we asked the participants to indicate their current mood on a nine-point self-assessment-mannequin (SAM) scale (adopted from [2]) before and after the period of rivalry stimulation. Our results indicated that only the glum clips influenced the participants' mood reliably, while cheering clips did not. Moreover, we did not found any changes in the alternation rate during binocular rivalry dependent on the current mood. In conclusion, we could neither reject nor confirm Pettigrew's finding, because we failed to induce mirth. That glumness does not affect binocular rivalry (in contrast to Pettigrew's mirth), however, suggests that not all moods affect the alternation rate during binocular rivalry.

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Temporal Preparation Decreases Metacontrast Masking

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When participants can anticipate the temporal occurrence of a stimulus, reaction time (RT) to this stimulus is especially short. In order to investigate whether temporal preparation facilitates perceptual processing, we employed a metacontrast masking paradigm. Temporal preparation was manipulated in a blocked foreperiod paradigm, in which a warning signal announces the temporal occurrence of a forthcoming imperative stimulus. Participants had to discriminate whether a spatial gap within a Landolt-square was either on the right or on the left side. To obtain a masking function, the stimulus onset asynchrony (SOA) between the Landolt-square and the following mask was varied. The results replicate the RT benefit of temporal preparation. In addition, the common u-shaped metacontrast function of discrimination performance depending on SOA was attenuated by temporal preparation. Thus, the results demonstrate that temporal preparation improves perceptual processing.

Top-Down Control Over Visual Contrast Sensitivity

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The visual system's ability to adjust its contrast sensitivity to the ambient contrast level is known as gain control. Previous research has shown that the adjustment of contrast sensitivity is driven by stimulus parameters in a bottom-up fashion [1] and further is under attentional control [2]. Here we present evidence that contrast sensitivity is under top-down control. We paired an absolute identification paradigm with a cueing paradigm to measure identification accuracy for four low contrast stimuli that were intermixed with an occasional high contrast stimulus. Foreknowledge of the presentation of the high contrast stimulus was manipulated by presenting valid and invalid-cues. In Experiment I we found that identification and discriminability of low contrast stimuli was impaired only when the occurrence of the high contrast stimulus was unpredictable but not when it was predictable. Only a top-down gain control mechanism whose functions were to maximize discriminability while protecting the system from overload was consistent with the results. Experiment II provided further support for the idea that an important function of gain control is to protect visual mechanisms from overload. A fit of the Naka-Rushton contrast response model to our data suggested that the top-down control mechanism reduced the effective contrast of the visual pattern (contrast gain) and rescaled the response of contrast sensitive units (response gain).

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Visuomotor Priming Reveals Early Stages of Lightness Processing

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We studied the effect of a lightness contrast illusion on a visuomotor priming task. Speeded keypress responses to the arrangement of a dark and a bright luminance target were performed in the presence of preceding dark and bright flanking stimuli whose apparent lightness was enhanced or attenuated by a contrast illusion. When the illusion amplified apparent flanker contrast, flanker arrangements consistent with the target arrangement speeded responses, while inconsistent flanker arrangements prolonged them. When the illusion attenuated apparent flanker contrast, this priming effect reversed, despite the fact that the more luminant flanker always appeared brighter than the less luminant one. Our data demonstrate a qualitative dissociation of lightness processing in priming and conscious vision. We suggest that response priming effects, in contrast to conscious psychophysical judgments, reflect an early stage of lightness processing based on only local contrast information, which cannot be accessed by traditional psychophysical judgments.

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Updating of Attention Allocation in Parietal Cortex.

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Attention determines which aspects of the incoming sensory information are processed with priority. However, attention is seldom an all-or-none process but rather distributed over multiple kinds of incoming information, and this distribution must be updated according to events in the world. Despite its ubiquity, this dynamic updating has been little studied in psychophysics, and even less is known about its neural correlates. In order to investigate attention updating, we studied serial detection of targets in different dimensions (color, shape or motion) of visual stimuli. Performance changed according to target sequence, and could be explained by this simple behavioral model: Each detected target was followed by a discrete attention shift towards the dimension in which the target occurred, leading to a short-lasting, exponentially decaying performance benefit. Continuously changing performance over time reflected the dynamic updating of attention induced by the sequence of detected targets. BOLD signal predicted by this time-course of attention changes was found exclusively in left parietal cortex, suggesting that neural activity in this area directly reflects how world events influence the distribution of attention.

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Circadian Variations in Symbolic Magnitude Comparison: Evidence from a 40-Hour Constant Routine Protocol

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The aim of this study was to identify possible circadian rhythms in the comparison of number magnitude. Magnitude comparison of single digits is robustly characterized by a distance effect: close numbers (e.g., 5 and 6) produce longer reaction times (RTs) than numbers further apart (e.g., 8 and 2). This distance effect is assumed to reflect the difficulty of a comparison process based on an analogous representation of numerical magnitude. That is, close numbers are more difficult to compare since they have more representational overlap than far numbers. To assess the influence of the circadian clock, 12 male participants engaged in a 40-hour constant routine protocol, which started at 7 a.m. and ended at 23 p.m., 40 hours later. Each hour during the session, saliva samples were taken to measure melatonin as marker of circadian phase, and self-ratings were taken to measure subjective sleepiness. Performance in the digit comparison task was assessed every three hours. Over the course of 13 experimental sessions, performance showed a clear circadian rhythm: Short RTs were observed over the first day but increased towards late evening. The longest RTs were observed at the circadian nadir (at 3 and 6 a.m.) but recovered afterwards during the subsequent sessions (from 9 a.m. to 6 p.m., the next day). We also observed a clear symbolic distance effect. The size of the distance effect, however, did not change over the sessions, that is, both far and close digits were similarly modulated by the circadian rhythm. The result demonstrates an influence of circadian rhythm on performance in general, which do not differentially modulate the symbolic distance effect. In conclusion, this finding can be taken as evidence for the robustness of magnitude representation and its retrieval from memory.

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Shape- and Motion-Specific Impact of Perceptual Awareness on Event-Related Brain Potentials

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When two dissimilar images are presented to each eye separately, an observer experiences alternations between one image and the other. This perceptual alternation, known as binocular rivalry, is absorbing because stimulation and visual awareness are uncoupled: one of two physically present stimuli dominates perception while the other is suppressed. One of the open questions is, whether the time-course of suppression depends on the rivalling stimulus dimension. The goal of the present study was to investigate the first percept-dependent event-related brain potential (ERP) modulation and their cortical sources after stimuli rivalled either in shape or in motion. We used transitions between continuous rivalry and fusion stimulation. Stimuli were black/white radial frequency patterns of different shape in either concentric or excentric motion. The experiment consisted of two different tasks: in the shape task, observers reported the currently perceived shape (constant motion), whereas in the motion task, they reported the currently perceived motion (constant shape). ERPs were measured for transitions from binocular rivalry to binocular fusion. They can be distinguished into incompatible and compatible transitions depending on the prevailing percept of the observer. With incompatible transitions the percept of the observer is forced to change at the onset of the fusion stimulation, whereas with compatible transitions the current percept remains. The first percept-dependent ERP modulation occurred earlier when the transition followed shape rivalry (P1 component around 120ms) than when it followed motion rivalry (P2 component around 240ms). In both tasks, incompatible transitions elicited larger ERP-amplitudes than compatible transitions. Nondirectional primary current density maps of the difference between incompatible and compatible transitions revealed a similar cortical network of occipital, parietal and temporal regions for the ERP effects obtained within the shape and motion task. These findings suggest that the time-course of perceptual awareness in a binocular rivalry context is dimension-specific whereas the network mediating these effects is dimension-unspecific.

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Staring Makes Objects in the Visual Periphery Vanish by Filling-In the Pattern of Their Surroundings. A Novel Approach to Determining the Sizes of Perceptive Fields

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When one patiently stares at a well-defined fixation point (with one or two eyes, and without moving one's head), objects in the visual periphery observed from the corner of one's eyes are perceived to vanish. The illusion results from a filling-in of the surrounding texture. For instance, colored circular patches with diameters of up to 2, 5, 15, or 53° are perceived to vanish within 2–20 s at retinal excentrities of 3, 7, 20, or 53° respectively (with the last patch positioned completely outside of the field of binocular vision, i.e. close to the visual periphery). Even prominent light sources like the full moon can be perceived to vanish while one stares at a star seen rather close to it.

These vanished objects remain invisible while one blinks one's eyes, and even during passive and active rotation of the eyes up to 0.5 degrees. With larger rotations in any directions, however, the objects are perceived to immediately reappear. Cross-eyed vision reveals that both the vanishing and the reappearance of the objects can occur in one eye only or in both eyes. When the visual line is blocked by a white paper during the staring process, vivid afterimages of complementary colors are perceived at the very site of the vanished object, whereas the object itself remains invisible when the paper is removed.

We hypothesize that the maximum sizes of objects which can be made to vanish in the visual periphery by staring indicate the spatial extent of the perceptive fields [1]. These are known to increase with their distance from the foveal region and to cause the decrease of resolution of motionless objects in the visual periphery [2].

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Auditory Perception

Representation of Location and Identity of Natural Sounds in the Human Auditory Cortex

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Successful interaction with our environment entails both efficient identification and localization of auditory objects. Recent neurophysiological studies proposed a dual-path model in which auditory identification and localization follow anatomically distinct routes within the cortex. In the present study, we employed an fMRI-adaptation technique to test the representation of sound location and identity along the auditory processing stream. To this end, we presented subjects with pairs of animal vocalizations with a) same identity and same position, b) same identity and different position, c) different identity and same position and d) different identity and different position. While performing a same/different identity judgment, subjects showed significantly stronger fMRI responses for different versus same identity in the left Heschl's gyrus (HG), the left planum temporale (PT) and the bilateral superior temporal gyrus (STG). Significantly stronger fMRI responses for different versus same position were observed in the left posterior STG only. These results suggest position-invariant representation of auditory object identity in the left HG, PT and the more anterior aspects of the STG, but position-dependent representation of auditory objects within the left posterior STG.

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Redundancy Gains for Responses to the Onset and the Offset of Auditory Stimuli

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Auditory redundancy gains were assessed in two experiments using a simple reaction time paradigm. In each trial an auditory stimulus was presented either to the left ear, the right ear or to both ears simultaneously. Both experiments involved two tasks, namely the response to the onset (task1) and to the offset (task 2) of stimuli. In experiment 1, stimuli consisted of two pure tones of the same frequency. In experiment 2, a pure tone and white noise were used as stimuli. Replicating the results of a recent study [1], there was no redundancy gain in reaction time for the onset task in exp. 1 and only a small but consistent redundancy gain in the onset task of exp. 2. However there were large redundancy gains and evidence for coactivation in the offset tasks of both experiments. The different magnitudes of redundancy gains for the onset and offset tasks are discussed in the theoretical framework of the Parallel Grains Model [2].

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Computer Vision and Robotics

Insect Inspired Odometry by Flow Measurements Using Optical Mouse Chips

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In order to extract ego motion parameters from optic flow it is only necessary to monitor flow in a limited number of viewing patches taken from preferably opposite directions and distributed over a large solid angle [1]. Since optical mouse chips are available we have cheap (2.5 EUR), light (0.5 g) and fast (response $<$ 1 msec) flow detectors at our hands. We present a hardware realization of an odometer driven solely by flow measurements in a few directions in space.

The device contains eight optical mouse sensors (ADNS-2620, Avago) each provided with an adjustable plastic collimator lens (CAY045 Philips) of f = 4.6 mm focal length which images the environment onto the light sensitive area of the sensor. The mouse sensors sample about 1500 times/sec the light intensity on their 1x1 mm array of 18x18 light sensitive diodes. A fast on-chip digital signal processor (DSP) correlates the patterns of two consecutive samplings and evaluates the displacement between them. Via two serial lines to each sensor a microprocessor (μP) (CY7C68013A-56P, Cypress) reads information continuously from all sensors in parallel. The μP is connected via USB to a PC. Reading the information from all sensors (strictly in parallel), transferring them via an USB bulk transfer to the PC costs less than 2 msecs.

The device is mounted on a curricle moving on flat contrasted ground. Motion is restricted to two degrees of freedom : rotation about the high axis (yaw) and translation along the long axis. For each small time interval motion can be uniquely decomposed into rotation and translation. The response of all sensors to yaw was calibrated by performing a well defined pure rotation about the yaw axis and reading all sensors' response. A similar procedure was performed to calibrate translation along the long axis. In order to monitor a combined motion of any yaw with any translation we extract each component from the accompanied ensemble of sensor responses : we simply calculate a best fit of the actual response to a linear combination of yaw—and translation unit sensor responses.

A hardware demonstration of the device will be presented.

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A Biologically Motivated Approach to Human Body Pose Tracking in Clutter

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In this study we present a biologically motivated learning-based computer vision approach to human pose estimation and tracking in clutter. The approach consists of two interconnected modules: human posture estimation from monocular images and tracking a person's location in video footage. Full body pose estimation is approached with methods from statistical learning theory: A mapping from biologically plausible complex features (similar to [1]) into a pose space is learned using kernel based techniques (i.e. Support Vector Machines and kernel ridge regression). The pose space is derived from a human body model based on 3D joint positions.

To tackle the ambiguities inherent to the projection of a 3D scene onto a monocular image our approach employs a one-to-many mapping scheme which maps, in a mixture-of-experts fashion [2], to several possible 3D poses. A key feature of the presented framework is the feedback matching pathway which evaluates the likelihood of a generated hypothesis in an intermediate feature space based on a robust medial axis transformation. The approach of [3] is hereby extended to clutter. The fusion of bottom-up and top-down techniques exploits the advantages of both approaches by being able to generate multiple hypotheses fast in a feed-forward manner without losing the ability to evaluate the hypotheses in the original image space.

Tracking is investigated as the problem of finding a bounding box of a person throughout a video sequence taking into account possible shape deformations. Based on the ability to track a person a temporal filtering framework with constraints of natural movement is employed to further disambiguate several hypotheses and to arrive at a stable and robust pose estimate.

To generate the needed amount of training images with corresponding ground-truth pose information we use realistic computer graphics models driven by motion capture data embedded into clutter by alpha-blending. Overall, we explore the robustness of our framework against background changes and its generalization capabilities to novel actors, actions and real world imagery.

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A Smart Camera Approach to Distributed Tracking and SVM Based Activity Recognition in Privacy Sensitive Areas

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Surveillance systems based on distributed sensor networks are massively emerging today, as the interest in enhanced safety in this ever changing world gets more actual than ever. Traditional "CCTV" surveillance systems with their centralized processing and recording architecture together with a simple multi-monitor visualization of the raw video streams bear several drawbacks and limitations. The necessary communication bandwidth to each camera and the computational requirements on the centralized servers strongly limit such systems in terms of expandability, installation size and spatial / temporal resolution of each camera. Additionally, the visualization is counter intuitive and fatiguing due to the massive load of raw video data. Most important to note is however the total lack of privacy.

We present a system consisting of a distributed smart camera network that allows for embedded video analysis in real time. This approach enormously increases the privacy as no video feed ever leaves any camera. Person tracking serves as basis for activity recognition of particular events (e.g., falling person). Each smart camera is capable of embedded classification of events based on Support Vector Machines (SVM). First, significant training data needs to be collected and labeled offline. After cross-selection is performed to find optimal model parameters, the trained kernel is loaded onto each smart camera where classification is performed in real-time for each tracked object. In case of falling person detection, first experiments showed that especially a combination of aspect ratio and histogram features performs quite well. Only the results of the tracking and activity recognition are transmitted to ensure privacy. Our flexible Plug'n'Play style architecture in addition with the low bandwith of the transmitted events and tracking results allows for excellent scalability of the distributed network.

The inter-camera tracking results are embedded in one consistent geo referenced 3D world model and can be visualized in three different ways:

1. tracking results of the camera network within 3D models acquired by 'the Wägele' and visualized in XRT.

2. tracking and activity results within Google Earth with floor plan overlay.

3. tracking and activity results within a floor plan which is embedded in a web 2.0 application.

This offers a visualization more abstract from the camera perspective yet more intuitive in terms of integration. Only relevant information is presented in order to get a better general idea of the monitored scene. For post event visualization, all information is stored in a database. Additionally, an alarm handler can automatically inform attendants by SMS or phone call in case of emergency. We have set up a prototype video analysis system with 4 smart cameras to help the elderly. It has been running 24/7 for 7 weeks now and shows quite promising performance.

Towards Local Navigation Strategies Based on Robust Optical Flow Computation

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Cognitive maps, as applied to robot navigation, usually contain only landmark information that is stable over large time periods. In order to make use of such a map, e.g. for executing route plans, the robot also needs to be able to react to unpredictable events, e.g. dynamic changes or other uncertainties. Because of their capability to react quickly to appearing obstacles insects have often been used as examples for designing motor controls applied in autonomous robots. A view on the visual system of insects reveals that the poor spatial resolution is compensated by an excellent temporal resolution. Some insects are capable to perceive over 300 images per second whereas humans are limited to about 60–65 images per second. Therefore flying insects are able to robustly determine the spatial structure of the environment based on fast and precise flow computation. In order to simulate the insects vision we use a catadioptric vision system (a panoramic mirror enabling a 360 degree field of view) mounted on a Khepera-Robot. In a first step the optical flow field is computed using the Lucas-Kanade-Algorithm, a standard differential technique which uses a weighted least square estimate of the brightness change constraint equation. In a second step, local flow estimates are integrated over specific regions of the robots field of view using a robust statistical estimator used to solve the problem of strong outliers. In order to build a reactive system, we directly use the output of the flow computation as an input to the motor controller instead of reconstructing the local environment. One of the initial results is the robots capability to centre in a corridor, adjusting its speed to the width of the corridor so that it moves slower and thereby saver in narrow passages. The derived motor controller is based on the assumption that the magnitude of the integrated translational flow is indirect proportional to the distance. Therefore the field of view is divided into two hemispheres and the robot always orients towards the smaller flow until a balance is achieved. If only one wall is visible the robot tries to keep a fixed distance to the wall. This behaviour is used to bridge gaps in the corridor. Finally the robot can dock to a wall by adjusting its velocity with respect to the distance to the wall until it grinds to a halt.

SAD—A Novel Multisensor Scene Acquisition Device

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Many approaches to 3D scene acquisition with a variety of possible sensor-setups have been presented in the last years, many of them employ multiple laser scanners mounted on small carts [1] or even real cars. In contrast, we present a Scene Acquisition Device (SAD) dedicated to the acquisition of 3D models in complicated environments where small dimensions and simple usability are essential.

The proposed system consists of three sensors: A time-of-flight range sensor (PMD Vision 19k) combined with a standard color camera (Matrix Vision BlueFox) and a miniature inertia sensor (XSens MTi) build a handy acquisition device that allows for fast interactive capturing of color and geometry in arbitrary environments.

To gain from the strengths of the different sensors we post-process the raw data employing color and depth information in an integrated manner. As stated by [2], high-quality color data can be used to improve geometry. In contrast to usual approaches, where color images are used for texturing only, we consider both modalities when removing outliers and smoothing the noisy low-resolution depth data. Therefore, an iterative outlier removal algorithm is proposed that classifies valid depth measurements based on their local neighborhood utilizing color and depth values. The classification result is further used in the second step where a global MRF-based noise reduction [2, 3] is applied. The post-processing results in clean and smooth datasets. Both optimization steps are performed in little computation time such that a live visualization in 3D enables the user to obtain a preview of the snapshots from freely chosen virtual view-points.

For the assembly of large scenes, several frames of the multisensor-system have to be registered in order to create consistent large models. Therefore, an initial orientation estimate is given by the inertia sensor.

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Learning the Influence of Spatio-Temporal Variations in Local Image Structure on Visual Saliency

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Computational models for bottom-up visual attention traditionally consist of a bank of Gabor-like or Difference-of-Gaussians filters and a nonlinear combination scheme which combines the filter responses into a real-valued saliency measure [1]. Recently it was shown that a standard machine learning algorithm can be used to derive a saliency model from human eye movement data with a very small number of additional assumptions. The learned model is much simpler than previous models, but nevertheless has state-of-the-art prediction performance [2]. A central result from this study is that DoG-like center-surround filters emerge as the unique solution to optimizing the predictivity of the model.

Here we extend the learning method to the temporal domain. While the previous model [2] predicts visual saliency based on local pixel intensities in a static image, our model also takes into account temporal intensity variations. We find that the learned model responds strongly to temporal intensity changes ocurring 200–250ms before a saccade is initiated. This delay coincides with the typical saccadic latencies, indicating that the learning algorithm has extracted a meaningful statistic from the training data. In addition, we show that the model correctly predicts a significant proportion of human eye movements on previously unseen test data.

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Robust Ego-Motion Estimation from Sparse Optical Flow

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One classical problem in computer and robot vision is the 3D ego-motion estimation of a moving observer (e.g. a walking/jumping/flying robot) based on visual inputs captured by an imaging system. Inspired by biology, some walking robots are equipped with a pair of stereo cameras as sensing devices, as the use of stereo with a known baseline can ease the perception of depth. For a flying robot with only a small payload available for vision sensors, it would be however advantageous to use a single camera.

This paper considers the specific problem of ego-motion perception using a single camera in both indoor and outdoor environment. Traditionally, this problem can be approached by applying a spatial-temporal constraint and computing a dense optical flow field between two images captured sequentially [1]. By definition, optical flow depends both on the motion of the observer and the structure of the observed objects in the field of view. Consequently, the obtained flow field may contain some erroneous estimates. As every other parameter estimation method, motion estimation from a dense flow field is very sensitive to noise measurement. In order to make robust ego-motion estimation we compute only a sparse optical flow based on the most significant image points and use robust techniques to remove errors caused by false matches.

Our approach operates by matching a set of carefully selected image points. The front end of the system is a feature tracker. Robust estimates of the camera motion are then achieved in real time based on the sparse optical flow generated by matched feature pairs. Experimental results on real video sequences demonstrate the effectiveness of the proposed approach. Building on the current result of ego-motion estimates, we will address in the future a further challenging problem of detecting individual moving objects around the moving observer. The final goal is the autonomous navigation of light-weight aerial vehicles in unconstrained natural environment, particularly in the presence of both static and moving obstacles.

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Multimodal Interactions: Sensory Integration

Cross Modal Transfer in Face Recognition

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Prior studies have shown that humans can recognize faces by touch alone but perform poorly in cross-modal face recognition [1]. Here we want to shed further light on haptic face recognition with four experiments using a well-defined stimulus face space based on the morphable MPI-Face-Database. Experiment 1 used a same/different task with sequentially presented faces which established that subjects were able to discriminate faces haptically, using short term memory. In Experiment 2 we used an old/new recognition task for which different sets of three faces (out of six) were learned haptically with three subsequent haptic test-blocks and one visual test-block. In contrast to Casey and Newell (2007) we used the same printed face masks for recognition in both modalities. We found that participants could recognize faces haptically although recognition accuracy was low (65%) and tended to decrease across blocks. Cross-modal recognition, however, was at chance level (48%). In Experiment 3, we changed the design such that haptic memory was refreshed before each test-block by repeated exposure to the three learned faces. We found that performance increased significantly to 76% and that it became more consistent across blocks. Most importantly, however, we found clear evidence for cross-modal transfer as visual performance rose above chance level (62%). Our results demonstrate that during visual face recognition, participants have access to information learned during haptic exploration allowing them to perhaps form a visual image from haptic information. In Experiment 4, we interchanged learning and recognition modality with respect to Experiments 2+3, testing within-modality recognition in the visual domain and cross-modal transfer by haptic recognition of the face masks. Using the same experimental design as in Experiment 2, we found that performance in the visual within-modality condition increased significantly to 89% and that it became more consistent across blocks (71% compared to 39% for Experiment 2). However, recognition accuracy decreased across blocks (from 96% to 87%). Interestingly, cross-modal performance was significantly higher than in Experiments 2 (at 69%) demonstrating a clear advantage in cross-modal transfer for vision as the learning modality. The reasons for the observed differences in cross-modal transfer remain to be investigated. Possible factors include differences in visual versus haptic memory permanence, vision as the dominant and therefore preferred learning modality, and finally the role of visual imagery in cross-modal transfer.

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Multisensory Interactions in Auditory Cortex

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An increasing body of literature provides compelling evidence that sensory convergence not only occurs in higher association areas, but also in lower sensory regions and even in primary sensory cortices. To scrutinize these early cross-modal interactions, we use the macaque auditory cortex as model and employ combinations of high-resolution functional imaging (fMRI) and electrophysiological recordings. Using function imaging in alert and anaesthetized animals, we reported that (only) caudal auditory fields are susceptible to cross-modal modulation: The fMRI-BOLD response in these regions was enhanced when auditory stimuli were complemented by simultaneous visual or touch stimulation [1,2]. To investigate the neuronal basis of this cross-modal enhancement, we recorded the activity of local field potentials and single units in alert animals watching complex audio-visual scenes. Our results show the following: Visual stimuli by themselves, on average, do not drive auditory neurons, but cause responses in low frequency LFPs. Combining visual and auditory stimuli leads to enhanced responses in the low frequency LFP, but to a reduction of firing rates. This audio-visual interaction was significant at the population level, and for about 10% of the neurons when tested individually. The interaction occurs only for well-timed visual stimuli, is strongest when the visual stimulus leads the auditory stimulus by 20–80msec, but is independent of the image structure in the visual stimulus. Similar visual modulation was found in the auditory core and belt. Our findings point to a very basic, stimulus unspecific visual input to auditory cortex and clearly support the notion that early sensory cortices are susceptible to cross-modal interactions. Especially, the finding that visual stimuli modulate the firing rates of individual neurons in auditory cortex suggests that the messages transmitted from these regions to higher processing stages do not only reflect acoustical stimuli but are also dependent on their visual context.

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Perceived Duration in Crossmodally Defined Intervals

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Sensory modalities do not act in isolation; they can influence one another. One intriguing example is temporal ventriloquism, where auditory and visual signals presented asynchronously appear to be closer in time than they are generated. The characteristics of this perceptual phenomenon are still not completely defined. In particular, it is not clear whether the order of presentation has an influence on the effect, whether there are temporal grouping effects for other modalities, and whether this effect only occurs for certain asynchronies of the signals. This study aims to fill this lack of knowledge by investigating how crossmodal temporal grouping affects perceived duration when onset and offset of a stimulus are defined by signals of different modalities in all combinations of auditory, visual, and tactile stimuli. To test this, a two interval forced choice (2IFC) paradigm was used, where participants had to judge which of two intervals was shorter. One interval consisted of a lasting sound (filled interval), the other interval was defined by two signals of different modalities at the onset and offset (empty interval). These two signals could be auditory (beep), visual (flash of a LED) or tactile (vibration on the participants' left index finger). Different stimulus onset asynchronies (SOA) between 100 and 900ms of the crossmodal interval were tested. Moreover, the order of the signals forming the empty interval was reversed. The duration of the filled interval was 30 to 170% of the duration of the empty interval. For each SOA of the empty interval, the point of subjective equality (PSE) for the duration was computed, which is the duration of the filled interval perceived to be equal to the empty interval. Results confirmed that for audiovisual intervals grouping effects were more salient with larger SOAs between the signals defining the empty interval. When the light preceded the sound grouping effects were also found for 500 and 700ms. For audiotactile intervals, instead, grouping effects occurred between 500 and 900ms but only when vibration preceded sound. Lastly, for visuotactile intervals, grouping occurred at SOA of 500ms but only when light preceded vibration. From these results, we can conclude that audiovisual temporal ventriloquist is only an instance of a more general crossmodal grouping effect that occurs with various modalities. Moreover, our data indicates that this effect acts differently on specific modality combinations. Temporal grouping is affected by both the time between the signals and their order of presentation.

Multisensory Interactions in the Claustrum

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The claustrum is an evolutionarily conserved structure, which in mammals, is well connected to most of the neocortex in a topographical manner. The claustrum has thus been deemed an important site for combining sensory information from different modalities, and its widespread projections put this structure in an ideal place to modulate processing in different cortical regions. Yet, our understanding of the properties and function of this structure is rather limited. Using extracellular recordings we map the sensory specific responses and quantify the integration properties of the claustrum of awake monkeys. Using paradigms employing visual, auditory and somatosensory stimuli, we find interactions between the audio-visual and the audio-somatosensory modalities, with the recorded responses exhibiting transient activity specific to the onset of the stimulus. At many sites, the responses to combined stimuli differ from the unisensory responses. Furthermore, comparing sensory responses recorded in the claustrum to those recorded at adjacent multisensory sites in insular cortex and putamen, we find that neurons in the claustrum often respond with much higher firing rates. In addition, we study the anatomical connectivity of the claustrum in the rat. Afferent and efferent projections subdivide this structure into sensory specific regions. Although particular modality specific zones have been shown to overlap, others remain aloof. This challenges the hypothesis that this structure facilitates multi-sensory integration across all modalities. Using anterograde and retrograde tracers we identify intra-claustral projections that connect the different sensory zones. Our results not only confirm previous reports of arealization, but also suggest new routes of multisensory interactions involving this structure. Altogether, our findings well support a role for the claustrum in facilitating the interaction of the different senses.

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Multimodal Interactions: Sensory-Motor Integration

The Locus of Execution-Related Dual-Task Interference

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Previous studies have shown that response execution of one task can cause interference with processing of another task. The present study assessed the locus of this execution-related dual-task interference. According to the response monitoring hypothesis, this interference arises from sensory feedback during movement execution which temporally occupies a central processing bottleneck. In contrast, the motor bottleneck hypothesis supposes a processing limitation at the motor level. In two experiments, which employed a novel variant of the psychological refractory period paradigm, participants performed ballistic movements of different length in Task 1. Experiment 1 revealed a clear propagation of movement duration in Task 1 onto Task 2 that demonstrates execution-related interference. In order to assess the locus of this interference in Experiment 2, we additionally manipulated S-R compatibility in Task 2. The results indicate that a substantial part of interference can be accounted by a motor bottleneck whereas the other part may be caused by response monitoring.

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Evidence of a Late Locus of Task-Switch Costs Within the Processing Stream

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If participants have to switch between two tasks, reaction time (RT) for task-switch trials is usually longer than for task-repetition trials. However, it is unclear where these task-switch costs emerge within the processing stream. A psychophysiological experiment using the movement precuing design assessed the locus of task-switch costs with the help of the lateralized readiness potential (LRP). The experimental setup was based on a study of Hsieh and Liu [1]. Participants had to switch randomly between two tasks which differed in their response sets. In half of all trials, a precue provided advance information about the forthcoming task. Both a precue effect and task-switch costs were observed on RT. The precue shortened the interval between stimulus onset and LRP onset suggesting a pre-motoric locus of this effect. More importantly, however, the interval between LRP onset and response onset was lengthened in the task-switch compared to the task-repetition condition. Therefore, the task-switch costs observed seem to arise after response hand selection suggesting a motoric locus. This evidence of a late locus of task-switch costs is at variance with current models of task switching. These models predict that task-switch costs result from processes which are either located in perceptual or response selection stages. It is hypothesized that the locus of task-switch costs differs depending on whether participants have to switch between stimulus or response sets.

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Neural Model for the Visual Recognition of Goal-Directed Hand Movements

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The visual recognition of goal-directed movements is crucial for the learning of actions, and possibly for understanding the intentions and goals of others. The discovery of mirror neurons has stimulated a vast amount of research investigating possible links between action perception and action execution [1,2,3]. However, the neural mechanisms underlying the visual recognition of goal-directed movements remain largely unclear. One class of theories suggests, that action recognition is mainly based on a covert internal re-simulation of executed motor acts, potentially even in a joint coordinate system. Another set of approaches assumes that a substantial degree of action understanding might be accomplished by appropriate analysis of spatio-temporal visual features, employing mechanisms that meanwhile are largely accepted as basis for the recognition of non-moving stationary objects. We present a neurophysiologically inspired model for the recognition of hand movements that demonstrates the feasibility of the second approach, recognizing hand actions from real video data. The model addresses in particular how invariance against position variations of object and effector can be accomplished, while preserving the relative spatial information that is required for an accurate recognition of the hand-object interaction. The model is based on a hierarchical feed-forward architecture for invariant object and motion recognition [4,5]. It extends previous approaches to complex stimuli like hands, and adds the capability for the processing of position information. The ability to recognize objects relies on a dictionary of shape-selective cells that are learned in an unsupervised manner from natural images. Feature complexity and invariance properties increase along the hierarchy by linear and nonlinear pooling operations. It is demonstrated that the model is able to correctly classify different grasp types and is suitable for determining the spatial relationships between effector and object, which are crucial for determining whether the action matches correctly the object affordance. The model demonstrates that well-established simple physiologically plausible neural mechanisms account for important aspects of visual action recognition without the need of a detailed 3D representation of object and action. This seems important since the robust extraction of joint angles from videos is a hard and largely unresolved computational problem, for which so far no physiologically plausible neural models have been proposed.

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An Activity Bubble Running along a Motor Schema

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Goal directed hand movement cannot be achieved by simply applying feedback. Subjects have to develop a motor schema to anticipate the path of a moving target and to compute an optimal course of interception. During the performance of perception-action-cycles such a schema may highly reduce the control load. A schema may arise from a population of interacting neurons probably in the cortex.

Assuming two 2D-layers of interacting neurons, one layer consists out of excitatory neurons, with activity Ae(x) in position x=[x1, x2] and one layer out of inhibitory neurons, with activity Ai(x). The four synaptic weight-functions between the neurons are defined by wee, wei, wie and wii which represent the spatial spread of synaptic interconnections. With respect to a given distance d=norm(x-x') the weights are monotonically decaying and have a Gaussian distribution of different width. The change of the activity Ae and Ai depend on mutual interaction between the neurons, determined by the synaptic weights and the nonlinear sigmoid activation function of each neuron, respectively. Thus we obtain a recurrent neural network eliciting complex cortical dynamics.

Normalizing excitation by global inhibition a point like stimulus causes a local bifurcation of the network by showing a stable 'bubble' (a local neural activation) of Gaussian shape. Depending on the asymmetry of the excitation spread function this 'bubble' may 'walk' around with different speed and in different directions, respectively. Given a certain trace of activated neurons in a third layer, which only influences the asymmetry of the excitation spread function, the 'bubble' should be attracted towards this activation trace. Close to the activation trace the 'bubble' remains within a certain potential wall, like being within a 'gutter'. Assigning a certain attractiveness to a selected goal the centre of the 'bubble' may run along the activation trace.

The activation trace may represent the current movement of the hand in the workspace. However, not in terms of position but in terms of movement direction a motion primitive is generated. This is in agreement with population coding in motor cortex M1. The representation of the motion trajectory was mapped to the workspace by means of a radial basis network. A controlled planar arm system is simulated and the resulting trajectory causes a modified or new activation trace in the neural net. Introducing a cost function repetitive arm movement modifies the activity trace and a movement schema can be learned. Corresponding with recent observations it can be shown that noisy hand trajectories become straight hitting a fixed goal. Applying different optimization criteria schemata of curved trajectories are learned which support the control of hand movements strongly.

Contribution of Vestibular Information to Perceived Walking Speed

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Although the vestibular system clearly plays an important role in the control of locomotion, it is not clear to what extent it is also involved in the perception of our own locomotion. We investigated whether vestibular information is used for the perceptual estimation of one's own walking speed. If vestibular information is used, perceived walking speed would be expected to be lower during walking in place on a treadmill than when walking at the same speed across the ground, as the forward acceleration of the head during walking is largely absent. To experimentally address this hypothesis, we used a circular treadmill setup, consisting of a large turn table (diameter 3.5m) and a motorized handlebar. Both could be actuated independently from each other. In this setup, walking behind the moving handlebar on the stationary treadmill stimulates both the otholiths and the semicircular canals, whereas this vestibular stimulation is much reduced when walking in place on the rotating treadmill. The biomechanical information is largely equal in these two conditions. Subjects had to judge their walking speed in a 2IFC task. In one interval, they walked around the stationary treadmill behind the moving handlebar at one of three standard speeds (31.7, 42.3, and 52.8 deg/s at a radius of 1.28 m, corresponding to tangential speeds of 0.71, 0.94, and 1.18 m/s, respectively). In the other interval, they walked in place at one of nine test speeds. Their task was to indicate in which of the two intervals they walked faster. Accelerations (20–30 deg/s) as well as the duration of the walking period (3–4 sec) were randomly set for individual intervals. A psychometric curve was fitted to the speed judgments for each standard speed, from which the PSEs were estimated. The results were in general agreement with the hypothesis. Subjects tended to underestimate their walking speed when walking in place relative to actually walking around. This underestimation, however, seems to be dependent on walking speed and varies considerably across participants. In conclusion, vestibular information is used for estimating perceived walking speed.

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Colour and Spatial Cue for Action: Subliminal Colour Cues Affect Motor Behaviour

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We addressed two important implications from Milner and Goodale's theory [1,2,3] on dissociation of vision for perception and for action. i) Colour processing in the Ventral stream is not integrated in the visual guidance of body movements; ii) The access of colour information to motor systems is obligatory based on visual awareness. To address the first notion we employed a redundant-target paradigm in which subjects reacted to spatial, colour or combination of both (redundant) targets. Further, our subjects reacted to isoluminant coloured targets preceded by subliminal incongruent ones. A second condition without subliminal priming target was compared against the first one. Subjects initiated each trial by pressing a button on the response box. After the short central fixation a stimulus appeared and the subjects were asked to respond as quickly as possible without making too many errors to the stimulus onset. They had to initiate left or right motor response according to the visualized target. We observed reaction time gain (responses are faster, on average, when two or more signals are presented simultaneously than when a single signal appears.) in the range of 23 to 33 msec across the subjects. Our interpretation is that the reaction time gain is resulting from combined sensory information in reaching some decision criterion. We also show that stimuli blocked from awareness (subliminal cues) are able to delay the fast motor responses. Overall, the results are inconsistent with the theory of independent action and perception pathways and provide behavioural evidence for interactions between ventral and dorsal streams.

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Visual Information and Compensatory Head Rotations During Postural Stabilisation

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This study investigated how human observers use visual information to stabilise posture. Participants were required to stand as still and stable as possible on a soft foam balance pad while fixating a small target at eye-height on a dimly lit lamp. The room was completely darkened such that no other visual information was available. The lamp was placed at either 0.4m, 1.16m, 2,33m, 3.5m, 4.66m or 5.82m distance from the observer. So far, no other study had investigated such a wide range of distances. Head position and orientation was measured at 120 Hz using a Vicon tracking system. Participants wore a helmet with infra-red reflecting markers. Each trial lasted 40 seconds, and 30 sec. breaks were taken between the trials. Room lights were switched on during the breaks in order to prevent complete dark adaptation. Postural stability was calculated by quantifying the most frequent sway velocity that occurred at the sampling frequency. This measure was found to be the most robust measure of postural stability, in comparison to other measures, such as sway trajectory length. Furthermore, RMS values for lateral and frontal sway were computed. Results showed that postural stability significantly decreased with increasing fixation distance. At 0.4m distance, the average sway velocity across 10 participants was 0.85 cm/s, and this value increased to 1.4 cm/s at 5.82m fixation distance. This means that the stability of the observers decreases with increasing fixation distance. With eyes closed, average sway velocity increased to 1.55cm/s. To investigate the influence of the target distance on the fixation behaviour, we analysed the yaw rotation of the head. A positive correlation between head orientation angle and head position in the mid-lateral plane was found. This means that during lateral postural sway, the head makes systematic compensational movements along the yaw-axis when observers aim to maintain fixation straight ahead. The correlation significantly decreased with increasing fixation distance and reached a plateau at about 2.5m. The decrease of postural stability at larger fixation distances also reached a plateau at about 2.5m. No correlation between head orientation and head position in the anterior-posterior plane was found. Further experiments which will also include eye-tracking will investigate how afferent visual information and efferent eye-and head movements contribute to human postural stabilisation performance.

Head-Trunk Relation Before and During a Turn: the Effect of Turn Angle

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During walking the behavior of the head and trunk are closely coupled. This becomes particularly clear while taking a turn. Here, we investigate this coupling during two phases of turning, before and during. Before a turn people make anticipatory orientations of the head into the direction of the turn. Previous research suggests that this anticipation occurs at a constant distance before the curve for different walking speeds. However, in most studies participants only performed 90° turns. We tested whether anticipation distance is invariant across different turn angles. As the turn progresses the head continues to look further into the turn than the trunk, and slowly converging towards the end of turn. An additional question here is the dependence of relative yaw between head and trunk on the turn angle. To answer these questions we measured head-trunk angles across a range of different turn angles. Participants followed predefined paths around obstacles with the radius of turn indicated by circles drawn on the floor. Turning angles ranged from 45° to 180° in steps of 45°. The position and orientation of both the head and trunk were measured using an optical tracking system. Two parameters were calculated from the data: head anticipation and maximum relative yaw. Head anticipation is the distance in space where the head starts to look into the upcoming turn. Maximum relative yaw is the maximum difference occurring between the yaw angle of the head and the trunk during a turn. Both head anticipation and maximum relative yaw increased with turn angle, although maximum relative yaw leveled off after 135°. In a second experiment, participants followed the same paths as in Experiment 1, but were not constrained in the turn radius. Results showed that turn radius decreased with increasing turn angle. Nevertheless, we found the same pattern of results as in Experiment 1. In conclusion, the relation between head and trunk both before and during a turn is dependent on the angle of turn one is about to make.

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Opposite Explicit and Implicit Processes of Adaptation to Changes of the Visuo-Motor Gain

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Previous research has shown that adaptation of movements to changes of the visuo-motor gain can occur implicitly, with participants not being aware of them. We investigated the influence of explicit information regarding changes of the visuo-motor transformation. Explicit knowledge gave rise to intentional adjustments of the movements. When implicit and explicit processes of adaptation were combined, the resulting size of the adjustments was the sum of the two components. This was the case when both explicit and implicit adjustments required a decrease of movement amplitude. Here, we examine their combination when they require opposite adjustments. In the experiment participants had to draw circles of constant size with a stylus on a writing pad. The position of the stylus on the pad was presented by means of a cursor on a computer screen. Participants were told that the ratio of the amplitude of the circles on the screen and the circles drawn on the writing pad (visuo-motor gain) was changed from 1:1 to 1.1:1 during some trials, so that circles shown on the screen were ten percent larger than circles drawn. To compensate for this change and to maintain a constant size of the circles on the screen, participants had to reduce the size of the drawn circles during the change of the visuo-motor gain. Participants were also told that the change of the gain was cued by a change of the colour of the cursor. The actual change of the visuo-motor gain was varied so that in some trials the instructed explicit knowledge was correct. In other trials the visuo-motor gain was changed to 0.9:1, requiring an increase of the size of the circles drawn, or it was not changed at all. Also, the change of the visuo-motor gain was cued by the change of the colour of the cursor in only 50 percent of the trials. Thus implicit processes of adaptation were also tested alone. The results showed additivity of explicit and implicit adaptation even when these processes contributed adjustments of circle size in opposite directions. Whereas interindividual variability of implicit adaptation was small, interindividual differences in explicit adaptation were large.

Thalamic Role in Perceiving Upright Body Position in Humans.

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The human evolutionary success of maintaining the upright position is achieved through the multisensory convergence of, at least, vestibular, visual, and somatosensory information. However, after brain damage, this multisensory integration that indicates verticality in a congruent manner may be disturbed, determining diverse disorders of posture and of balance control. Among them, one of the most intriguing dysfunctions is called "pusher syndrome" [1]. This is a severe disturbance of postural orientation induced by lesions centering on the posterior thalamus. The patients have a disturbed perception of the orientation of the upright body posture, tilted about 20° to the ipsilesional side, while they show undisturbed processing of visual and vestibular inputs determining visual vertical [2, 3, 4]. The aim of the present study was to investigate whether posterior thalamic strokes in patients with pusher syndrome cause abnormal perfusion in sub/cortical areas remote from the site of the lesion. We performed a group study in which we studied both the structurally irreversible damage identified through DWI/FLAIR and the pattern of (structurally intact but) dysfunctional tissue specified by perfusion-weighted imaging (PWI). We determined the common area(s) of structurally intact but dysfunctional cortical tissue by using spatial normalization of PWI maps as well as symmetric voxel-wise interhemispheric comparisons. The group analyses revealed that patients with pusher syndrome did not show distinctive perfusion abnormalities in addition to their thalamic lesions. We conclude that the lesions of the neural tissue in the posterior thalamus, rather than metabolic abnormalities in other, structurally intact sub/cortical structures, cause the typical impairment of upright body posture known as pusher syndrome. The present observations suggest that the human posterior thalamus is integral to sensing orientation of gravity and controlling upright body posture. Further, our findings propose a pathway for sensing the orientation of gravity and controlling upright body posture, separate from the one for perceiving the orientation in the visual domain [5].

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Visuo-Motor Integration in Human albinism—Abnormal Input to the Primary Visual Cortex Induces Abnormal Representations in Parietal Cortex

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Purpose: In albinism there is an abnormal representation of the ipsilateral visual field in the early visual cortex [1], which makes it a powerful model of cortical self-organisation in humans. Previous studies demonstrated that the abnormal input is organized as an orderly retinotopic map in the early visual cortex [2] and that it is made available for visual perception [3]. We investigated whether the representation abnormality persists in higher-tier areas and how it is processed during visuo-motor integration. Methods: With an event-related fMRI paradigm brain activity was studied during a visuo-motor memory task in 14 albinotic subjects and in 14 controls (3T, Siemens TRIO; analysis with SPM5): While the subjects monocularly fixated a central point, a coloured target embedded in an array (6.5° x 6.5°; centred at 5.5° left or right from fixation) of grey distractors was presented for 250 ms either in the left or right visual hemi-field. After a delay, subjects were prompted to press, according to the position of the previously presented target, the upper or lower response buttons for targets in the upper or lower visual field, respectively, either with the left thumb (blue targets) or with the right thumb (red targets). Results: In accord with the known variability of the extent of the representation abnormality [4], a strong misrepresentation of the visual stimulus was evident in half of the albinotic subjects tested. In these subjects the abnormality extended far into higher-tier areas up to the parietal cortex. In contrast, no abnormality of the sensory-motor representation was observed. Conclusion: Cortical self-organisation accommodates the abnormal representation of the ipsilateral visual field in great expanses of the visually driven cortex, but does not appear to induce an abnormal lateralisation of sensory-motor processing for visuo-motor integration.

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Perception of Time

Topography of Temporal Misperception During Saccadic Eye Movements

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A number of studies have shown in the last years that visual space is perceptually compressed when visual stimuli are flashed briefly before, during or after a saccade. Yet, it was shown only recently that also time perception is distorted during saccades: brief intervals between two flashed stimuli are underestimated perisaccadically. In some cases, perceived temporal order of stimuli is even reversed. These studies suggested, that time and space might be processed by similar neural networks. In our present study we hence investigated whether or not perisaccadic time-inversion is influenced by the position of the stimuli within the visual field. Eye movements were recorded in human subjects with an infrared eye tracker (EyeLink 2, SR-Research) running at 500 Hz. Visual stimuli were displayed on a CRT screen covering the central 39x29.5° of the visual field. In a first set of experiments, subjects fixated a target at [x,y]=[7.5°,0°], i.e. 7.5° left from the center on the horizontal meridian. 500 to 1000 ms after trial onset, the fixation target was switched off and a saccade target appeared at [x,y]=[+7.5°,0°]. Perisaccadically, two bars (39°x6°, presented for 10ms) were displayed with a temporal onset-separation of 50ms. One of the bars was presented at 12° above, the other at 12° below the horizontal meridian. Subjects had to indicate which bar appeared first. This first set of trials was meant to reproduce previously published results on perisaccadic time inversion [1]. Only Subjects showing this expected effect of time-inversion participated in the main experiment. Here, we presented square patches (2x2°) rather than bars. Across trials, these patches were presented at one of six possible horizontal positions, 4° above or below the horizontal median, respectively. Possible horizontal locations ranged from 12.5° degrees left from the vertical meridian (VM) to 12.5° right from the VM. About half of the subjects showed the effect of perisaccadic time-inversion in the first experiment (bars). In the main experiment (square patches), these subjects also showed a modulation of time perception. For some but not all positions, temporal judgment was reversed. Such inversion was found most often at the two most eccentric positions. Hence, our results provide further evidence for the notion that the processing of time and space are more tightly linked than previously thought.

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Crossmodal Simultaneity is Not Transitive

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Sensory processing times can greatly differ between the senses. Hence, signals from different modalities that are presented with a delay corresponding to the processing time difference between these modalities appear simultaneous to the observer.

We hypothesized that if processing is independent for each modality and if there is a common mechanism for the perception of simultaneity across modalities then subjective simultaneity should be transitive. For example, if modality A has to be presented 20ms before B and modality B 10ms before C to be perceived as synchronous, then modality A should be presented 30ms before C to seem synchronous with it.

Observers judged the temporal order of three different modality pairs (visual-tactile, tactile-auditory, and visual-auditory) for eleven stimulus onset asynchronies. Stimuli from the three conditions were not blocked but presented randomly to prevent attentional prior-entry effects that might lead to artifactual intransitivity.

From the responses, we determined the presentation delay leading to subjective simultaneity. To appear synchronous the visual signal has to be presented 34ms before the tactile, the tactile 55ms before the auditory, and the visual 28ms before the auditory. These results deviate significantly from transitivity. We conclude that either stimulus processing time in one modality depends on which other modality it is paired with, or the notion of a common mechanism for crossmodal simultaneity has to be rejected.

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Subjective Temporal Expansion or Simply Response Bias?

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Tse, Intriligator Rivest, and Cavanagh [1] have shown that subjects judge the duration of oddball stimuli longer than the duration of reference stimuli. They attributed this effect to a subjective temporal expansion of the perceived oddball duration. The oddball effect in their study was unusually large compared to similar findings reported by Ulrich, Nitschke, and Rammsayer [2]. The size of this oddball effect may be entirely due to the oddball catching attention. However, it may also be due to a bias in the psychophysical procedure employed by Tse et al. These authors used the method of constant stimuli with stimuli levels distributed asymmetrically around the reference duration. This might have artificially enlarged the oddball effect in their study. The present experiment examines this hypothesis. In agreement with this hypothesis, employing the asymmetrical constant procedure resulted in a clearly larger oddball effect when compared with an adaptive procedure that avoids such an asymmetrical distribution. Nevertheless, the oddball effect was still present for the adaptive procedure. Thus, our results strengthen the notion that the duration of unexpected stimuli appears longer than the duration of expected ones.

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Perceptual Neuroscience

Multistable Perception: ERP Correlates of Perceptual Stability Across Different Classes of Ambiguous Figures

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Background. A stable visual percept of the world rests on interpretive processing of incomplete visual information. In the case of ambiguous figures our perceptual interpretation is only temporarily stable and alternates between two or more mutual exclusive and in general equitable outcomes, although the observed visual object stays unchanged. We can delay a perceptual reversal volitionally to a certain degree, however, we cannot eliminate perceptual instability totally. Minuscule modifications of an ambiguous figure can make it unambiguous and thus stabilize the percept dramatically, while keeping the qualitative perceptual impression nearly unchanged. In the present study we compared the ERP correlates of the neural representations between two classes of ambiguous figures and their unambiguous counterparts. Methods. In separate experiments, ambiguous stimuli (Necker lattice, Old/Young Woman) and unambiguous stimulus versions appeared repeatedly for 800 ms after breaks of 400 ms. Subjects compared successive stimuli and indicated in different experimental blocks whether they perceived a "reversal" or "stability" (two successive stimuli in the same orientation) at stimulus-onset. EEG data were recorded and averaged with regard to stimulus type (4) and electrode (13). Results. For each stimulus class (lattices and faces) we found two major differences between ambiguous stimuli and their unambiguous counterparts: (1) An early occipital/parietal difference beginning at around 80 ms (lattices) or 110 ms (faces). (2) A P300-like positive component most prominent at parietal and central positions at around 400 ms in the case of the unambiguous stimuli, which is much weaker (about 25%) in the case of the ambiguous stimuli. Discussion. The time range of the early occipital modulation is very similar to the occipital "Reversal positivity" found by Kornmeier & Bach (2006). We interpret it as a correlate of the initial difficulty for the perceptual system to treat visual information with a high degree of ambiguity. The amplitude of the late positivity may indicate the degree of stability the perceptual system had reached given a specific type of visual input.

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Multistable Perception: Does Stability of a Neural Object Representation Depend on Attention?

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Background. When we observe an ambiguous figure, our percept is unstable and alternates between two or more mutual exclusive and generally equitable interpretations. Minuscule modifications of an ambiguous stimulus can make it unambiguous, thus stabilizing its percept dramatically while leaving the qualitative perceptual impression unchanged. Kornmeier et al. (this conference) recently found remarkable differences between ERP correlates of neural representations of ambiguous figures compared to their unambiguous counterparts. In their experiment both the ambiguous and the unambiguous stimuli had been in the focus of attention. In the present study we investigated whether these strong ERP differences also occur if the figures—although present—are not in the focus of attention. Methods. In separate experiments a Necker lattice and unambiguous lattice variants appeared repeatedly for 800 ms with inter-stimulus intervals of 27 ms. 15 participants compared in different experimental blocks either successive lattices or successive fixation targets (the letter "A" or the digit "8", which randomly alternate) and indicated perceived changes in orientation of the lattices or changes in fixation target between letter and digit. EEG was recorded and averaged with regard to lattice type (ambiguous or unambiguous), focus of attention (lattice or fixation target) and electrode (4 positions). Results. We found two major differences between ambiguous lattices and their unambiguous counterparts: (1) An early occipital/parietal difference between 80 and 100 ms, which is independent of the focus of attention and (2) a P300-like positive component most prominent at parietal and central positions at around 400 ms in the case of the unambiguous stimuli, which is much weaker (25%) in the case of the ambiguous stimuli. This difference is only present if attention is focused on the lattices. Discussion. Like in the study by Kornmeier et al. (this conference) the early effect points to the "Reversal Positivity" reported by Kornmeier & Bach (2006) and may indicate the initial difficulty for the perceptual system to treat the ambiguous information, irrespective of attention. We interpret the remarkable size of the late ERP difference as an index of different degrees of stability of the particular neural representation (weak with ambiguous, strong with unambiguous stimuli). The present findings suggest that neural processing stops at an intermediate step, if the lattices are not the focus of attention.

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Neural Basis of TMS Induced Suppression During a Visual Discrimination Task

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In Transcranial Magnetic Stimulation (TMS), strong magnetic pulses delivered by a coil placed over the subject's head are used to induce neural activity in a focal area of the brain. TMS can be used to demonstrate a causal relationship between behavior and the neural processing in a brain structure of interest by showing that a subject's task performance is diminished during TMS stimulation of that structure (i.e., the "virtual lesion" approach [1]). We addressed two questions in the current study: 1) How well does the position of the maximal TMS effect coincide with the brain activation pattern observed during the task using other neuroimaging techniques such as fMRI or PET? 2) Which visual area is most critical for conscious perception of a visual stimulus, i.e. which visual area has to be disturbed after stimulus presentation to diminish the recognition performance significantly? ("visual suppression" effect [2,3]). In all subjects, the spatial pattern of the TMS effect was smooth and the coil positions at which the maximal suppression occurred were located next to each other. This indicates that the TMS target was a single continuous brain structure and not, e.g. two or more separate sub-areas. The Center of Gravity (CoG) of the TMS map was consistently positioned over the inferior part of the superior occipital gyrus. As expected, the fMRI activation pattern was rather extended and covered several visual areas. The TMS CoG was consistently located over the medial-inferior part of the fMRI activation. Visual mapping [4] delineated the TMS CoG being significantly closer to the CoG of V2 than to any other visual area. Mean deviation of TMS CoG from V2 CoG obtained with fMRI was 5.1mm (SE 0.6mm, n=7), showing a good spatial congruence between these two neuroimaging techniques. Several control studies were performed to test for possible involvement of other visual areas. The findings suggest that V2 and not primary visual cortex V1 is the brain area primarily targeted in visual suppression. In consequence, our data does not support the special role of V1 in conscious visual perception as previously suggested by several authors (for review see [5]).

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Electrophysiological Effects of Interocular Incongruence During Sequential and Simultaneous Binocular Stimulation

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Human binocular vision normally results in the fusion of both eyes' information. If, however, that information conflicts between the eyes, rivalry—entailing perceptual alternations between both eyes' images—occurs instead of fusion. Here, I investigate electrophysiological responses to incongruent and congruent binocular information that is presented either sequentially or simultaneously. Initially, one eye viewed a grating and the other viewed a grey field. Then, during sequential binocular stimulation, the first eye's grating was turned off and a grating to the second eye turned on; then stimulation went back to the original. During simultaneous binocular stimulation, the stimulus to the first eye remained while a grating to the second eye was turned on. The second eye's grating was either of the same (congruent) or perpendicular (incongruent) orientation to that of the first eye's. Stimuli to both eyes were flickered in different frequencies (12.5 Hz on the left eye, 7.1 Hz on the right eye). For simultaneous presentation, i.e. in the epoch after the onset of the second eye's grating, spectral EEG-amplitudes in the stimuli-driving frequencies differed depending on interocular incongruence: Between 300 and 500 ms after the second grating's onset, amplitudes were larger if the second grating was congruent to the first grating than if it was incongruent; whereas between 600 and 900 ms after the second grating's onset, amplitudes were larger if it was incongruent than if it was congruent. Spectral EEG-amplitudes to sequential presentations did not show dependencies on stimulus incongruence between the first and second grating. Event-related potentials (ERPs), however, yielded larger P1- and N1-amplitudes for incongruent than congruent stimuli for both, sequential and simultaneous presentations after the second grating's onset. These results suggest that the same stimulus presented to one eye is processed differently depending on if its information conforms with the stimulus already being presented to the other eye. The differences commence with initial stimulus processing (ERP effects) and prevail for simultaneous binocular stimulation resulting either in fusion or rivalry (spectral EEG amplitude differences).

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Perceptual Segmentation of a Visual Scene Does Not Modulate Temporal Synchrony and Rate Enhancement in Primary Visual Cortex

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Introduction. Temporal synchrony [1] as well as rate-enhancement [2] of neurons in primary visual cortex (V1) have both been suggested to be involved in the solution of the binding problem. Both phenomena were found to covary with the perceptual segmentation of a scene [1,3]. We tested whether perceptual segmentation alone is sufficient to cause modulations of temporal synchrony and firing rate of neurons in V1.

Methods. Two overlapping rectangles ($\sim$6.5°x2°) monocularly forming a cross were presented binocularly on a Wheatstone stereoscope. Horizontal disparity of the rectangles was manipulated to mimic stimulus configurations with either the horizontal or the vertical rectangle in front of the other. A macaque monkey performed a relative disparity judgment task, while local field potentials (LFP) and multiple unit activity (MUA) were recorded with a 2x8 microelectrode array in the upper layers of V1. Stimuli were positioned so that half of the receptive fields (RFs) of the neurons were located on the overlapping part of the rectangles, while the others were located on the horizontal rectangle. The surfaces of the rectangles were manipulated to yield conditions either with or without locally unambiguous depth cues.

Results. In the locally unambiguous condition we found both rate-enhancement of neurons coding part of the figure and decoupling of groups of neurons coding different parts of the scene. These findings are in keeping with previous results [1,2]. In contrast, none of the effects were observed in the locally ambiguous condition, despite the fact that responses of the monkey were almost as accurate. The decoupling in the unambiguous condition was observed as early as 64 ms. Rate enhancement was observed from 100 ms after stimulus onset.

Conclusions: Our results are clear evidence that the perceptual segmentation of a scene by itself is not sufficient to modulate either temporal synchrony or rate enhancement. Both effects were observed only when the segmentation of the scene was supported by local features, in this case relative disparity. Timing of the effects suggests that binding by synchrony but not figure enhancement might support the process of segmenting the scene in the presence of local cues.

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Pinwheels vs. Bow Ties

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"Optical imaging" of the visual cortex after application of variously oriented visual stimuli provides an opportunity to test different models of the distribution of orientation sensitive neurons over the surface of the cortex. Rectilinear "slabs" of uniform orientation are not supported by the evidence. What is compatible with the optical imaging is the arrangement of neurons with different orientation around centers, regularly spaced at distances of about 0.5 mm in a hexagonal array. According to a model proposed in 1979 [1], the orientations to which the neurons are sensitive should be arranged either radially, or, more likely, like the tangents [2] of circles around said centers, whereby in either case twice the same orientation occurs in opposite positions of the "hypercolumn" thus defined. For this reason each colour, indicating a certain orientation on the optical recording maps, should form a blotch the shape of two sectors meeting at the center of the hypercolumn. We chose the term "bow tie" for this configuration, to match the facetiousness of the competing term "pinwheel". The centers of the hypercolumns very likely coincide with the so-called cytochrome oxidase "blobs" which are spaced at the same distance. The fact that within these "blobs" orientation tuning of cortical neurons becomes rather undefined [3], makes the array of orientations around these centers less spectacular, and indeed other interpretations of the coloured maps were put forward. "Pinwheels" stole the show, i.e. centers around which neurons with different orientation sensitivity crowd with the colours representing their orientation clashing without interposed indifferent regions. In these pinwheels each of the different orientations occurs only once as you go full circle around their center. They most likely correspond to the corners between the hypercolumns in their hexagonal array, and the different orientations within one "pinwheel" most likely belong to three different hypercolumns that meet there [4].

The distinction between the two entities, orientation hypercolumns and pinwheels may sound academic but becomes crucial when one endeavours to underpin orientation specificity of cortical neurons with schemes of neuronal interactions at the elementary level. This is fairly easy in the case of the hypercolumns under the assumption that in their centers are housed special inhibitory neurons [2], while a similar elementary scheme was never found as an explanation of the pinwheels.

On the coloured maps obtained with "optical recording" it is possible to discern both "pinwheels" and "bow ties" as an aid to the localization of the two types of centers.

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Research Methods and Techniques

On Estimating the Difference Limen in Temporal-Discrimination Tasks: A Comparison of the 2AFC and the Reminder Method

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We estimated the difference threshold (DL) in a temporal discrimination task (auditory and visual modalities) with the two most commonly employed methods in psychophysics for estimating the DL (i.e. 2AFC task and the reminder task). We also combined the two methods with two procedures for data collecting (i.e. adaptive and non-adaptive procedures). Although the two procedures produced virtually identical DL estimates, surprisingly, the 2AFC method produced DL estimates that were twice as high DL estimates as the reminder method. This outcome suggests that the method for estimating the DL matters, although in psychophysical research both methods are assumed to produce the same DLs.

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Tactile Perception

How Force and Position Signals Integrate in Haptic Shape Perception Under Variations of Exploratory Direction and Exploring Effector

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When sliding a finger across a surface, the finger position follows the surface geometry (position signal) and at the same time the finger is exposed to patterns of forces related to the slope of the surface (force signal; [1]). The integration of force and position signals into shape, perceived by active touch, has been demonstrated to be consistent with principles of optimal integration known from passive perception [2]. That is, force and position signals are integrated into a shape percept by a weighted averaging scheme, whereby the signal weights shift with the signal reliabilities [3, 4]. Here, we studied the influences of a) the direction of the exploratory movement (relative to the body) and b) the exploring effector (thumb vs index finger) on signal processing. Using a PHANToM force feedback device we constructed small virtual bumps (<6 mm). Force and position signals to the bumps differed as to the indicated bump amplitude. Participants compared these bumps to bumps with consistent signals (Experiment 1, method of constant stimuli) or they adjusted the amplitude of a visually presented bump to the previously felt amplitude (Experiment 2). Results confirm that the integration of force and position signals follows a weighted averaging scheme under each exploratory condition. Thereby, variations of—particularly—exploratory direction influence the relative weights of the signals, the perceptual reliability and—unexpectedly—perceived bump amplitude. Additional data demonstrate that—if having the choice—participants prefer exploratory directions that are accompanied by the most reliable percept. Thus, the findings clearly demonstrate that exploratory behavior during active touch influences signal processing. Further, they suggest that participants can exploit these influences for the purpose of reliable haptic perception.

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Influence of Parametric Variation in Exploratory Movement on Signal Integration for Haptic Shape Perception

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When sliding a finger across a bump on a surface, the finger follows the geometry of the bump, i.e., the finger moves up and down providing a position signal to the bump. At the same time, forces related to the slope of the bump accelerate and decelerate the finger providing a force signal to the bump [1]. Consistent with the Maximum Likelihood Estimate (MLE) [2] model haptically perceived shape can be described by the weighted average of the shape signaled by the force and position signal, respectively [2, 3]. Here we investigated—for the haptic perception of bump amplitude—the effects of the movement parameters pressure and velocity on the signal weighting, as well as on the discrimination threshold. Using a Phantom force feedback device we created bump stimuli, in which the amplitude indicated by the force signal differed from the amplitude indicated by the position signal. In a 2-IFC paradigm participants had to compare the felt amplitude of such "discrepant" stimuli (standards) to stimuli with consistent signals (comparison). Using the method of constant stimuli we fitted individual psychometric functions to the data and, thus, determined the points of subjective equality of standards with discrepant signals to the comparisons with consistent signals (PSE) and the 84%-discrimination thresholds. From the PSEs, we further calculated the relative weights of the force and position signal. The relative signal weights as well as the discrimination thresholds systematically depended on the movement parameters pressure and velocity. The relative force signal weight increased with increasing pressure and decreased with increasing finger velocity. The discrimination thresholds were lower when participants explored with high as compared to low pressure. Thus, we demonstrated that variations in pressure and velocity of the exploratory hand movements systematically modulate the integration of redundant signals to shape in active touch.

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Auditory and Visual Stimuli Alter Tactile Motion Perception

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Recently Sekuler et al. [1] investigated the motion-bounce illusion and found that sound can influence ambiguous visual motion perception. Here we investigated the motion-bounce illusion in the tactile-auditory and the tactile-visual domain, respectively. Using a vibro-tactile belt consisting of 7 vibrators we generated tactile apparent motion stimuli by sequentially activating neighboring motors with an onset of 200ms between the motors. Starting at the left and the right hip, two tactile motion stimuli run towards each other. On the body midline an ambiguous event was perceived: either the transition of both stimuli with continuing motion trajectories or a bounce event followed by the reversal of the movement direction. Presenting just the tactile motion stimulus resulted in an ambiguous percept. In the tactile-auditory condition the presentation of an auditory beep 200ms before the collision was sufficient to disambiguate the percept such that a significantly higher proportion of bounces was reported. The presentation of the sound at the time of the tactile collision event or 400ms before reduced the proportion bounces reported and became indistinguishable from the uni-modal baseline condition. In the tactile-visual condition the presentation of a flashlight at the time of the tactile collision, 200ms or 400ms before the collision induced a higher proportion of bounce reports. This indicates that the temporal window of audio-tactile integration is comparable to that found in the visual-auditory domain. These results suggest that similar supramodal mechanisms exist for apparent motion perception.

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Visual Cognition: General

Location Priming in Visual Search in Patients with Unilateral Left and Right Lesions with and without Parietal Involvement

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Visual search requires "spatial remapping", the ability to establish a spatio-temporal contingency between successive visual images provided by the retinae [1]. The integrity of this ability is indicated, for example, by location priming, an effect observed in a given visual search trial as a function of the preceding trial: Targets appearing at previous target locations are detected faster and more accurately (facilitation), while detection of targets at previous distractor locations is slower and more error-prone (inhibition). As a first step to the analysis of spatial remapping deficits in patients with parietal lobe injury, the present study investigated the question whether location priming can be appropriately used for that purpose. To that end, we assessed the effects of location-based facilitation and inhibition in patients with unilateral left- or right-hemispheric lesions, with or without parietal involvement, respectively. We used a priming of pop-out paradigm [2] without a spatial remapping requirement. Under such conditions, preserved facilitation and inhibition would be expected in patients with parietal lesions.

Three out of four patients with left parietal lesions, and five out of seven patients with right parietal lesions showed priming effects comparable in size to normal controls. One patient with a left parietal lesion and one patient with a left-sided lesion outside the parietal lobe did not show facilitation, and two patients with rather extended right parietal lesions did not show inhibition. Based on this preliminary data it is suggested that location priming can be used to assess spatial remapping deficits underlying disturbed visual search performance in patients with parietal lesions. However, for patients with right parietal lesions lesion size seems to be an important issue to be considered. In further investigations, implementing spatial remapping requirements into a priming of pop-out paradigm we expect, as a sign of deficient remapping mechanisms, altered location priming effects in patients with parietal lesions but not in patients with lesions outside the parietal lobe as well as in healthy subjects.

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Personal Exploratory Experience of an Object Facilitates Its Subsequent Recognition

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Current research shows that human object recognition is sensitive to the learned order of familiar object views (e.g. [1]). This temporal order of views could be determined by how an observer manipulates an object during learning e.g., rigid rotations in depth. In fact, the freedom to manipulate objects during learning is also known to improve subsequent recognition from single static images [2]. In this study, sixteen participants learned novel 3D amoeboid objects by manipulating them in a virtual reality environment. This required the use of a marker tracking system (VICON) and a head-mounted display (z800 3DVisor eMagin). Our participants handled a tracked device whose spatial coordinates, relative to the observers' viewpoint, determined the position and orientation of a virtual object that was presented via the head-mounted display. Hence, this device acted as a physical substitute for the virtual object and its coordinates were recorded as motion trajectories. In a subsequent old/new recognition test, participants either actively explored or passively viewed old (learned) and new objects in the same setup. Generally, "active" participants performed better than "passive" participants (in terms of sensitivity: d'=1.08 vs. 0.84 respectively). Nonetheless, passive viewing of learned objects that were animated with their learned motion trajectories resulted in comparably good performance (d'=1.13). The performance decrease was specific to passively viewing learned objects that either had their learned motion trajectories temporally reversed (d'=0.69) or followed another observer's motion trajectories (d'=0.70). Therefore, object recognition performance from passively viewing one's past explorations of the learned object is comparable to actively exploring the learned object itself. These results provide further support for a dependence on temporal ordering of views during object recognition. Finally, these results could also be considered in the context of studies that highlight the human ability of discriminating one's own actions from other people's actions e.g., hand gestures, handwriting, dart-throwing, full-body walking and ballet (for discussion and examples, see [3]). Here, our study also showed better recognition from viewing videos of self-generated actions. Nonetheless, this recognition benefit was specifically for the learned objects, which were not concretely embodied in the observer's person. Moreover, animating new objects with the participants' own actions did not increase their familiarity. We conclude by suggesting that our observers' did not merely show a familiarity with their past actions but rather, with the idiosyncratic visual experiences that their own actions created.

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Searching Again: A Memory Recency Effect in Repeated Visual Search

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Visual search often involves searching the same environment, consecutively, for a number of different targets. We used a repeated-search paradigm and measured eye movements to study such search and to investigate if search benefits from previous exposure to the same display. In the experiment participants searched the same display twice for two different targets. In each search the target could be either present or absent. Simultaneously to display onset a target was announced through loudspeakers (search 1). When the participant had made a present-absent manual response, a second target was announced (search 2). The location of the target in search 2 was kept constant relative to the last fixated item in search 1. Manual responses were faster in search 2 than search 1 regardless of whether a target was present or absent in search 2. Eye movement recordings demonstrated that the time necessary to find a target letter in search 2 depended on when that letter was last fixated in the previous search. This fixation recency effect lasted for about four fixations. In addition, when a target was absent during search 2, subjects were less likely to refixate a distractor if it had been recently fixated in search 1 and refixations tended to occur later on in the search. These results provide evidence for a limited capacity short-term memory store in this kind of visual search.

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Reading Perception-Perceiving Literature: an Interdisciplinary Approach.

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We want to present the results of an interdisciplinary project between the Departement of International and Comparative Literature Tübingen and the Max-Planck-Institute for Biological Cybernetics Tübingen in which we addressed the following questions: How is the topic 'perception' researched by the different diciplines, do they deal with the same phenomenon and forms of representations of perception or is there no or only a small intersection of the objects of investigations and can one method profit from or influence the other? Particulary it will be discussed a) how the issue of ambivalence/polyvalence and its (literary) perception is treated in both fields and b) if there are any possibilities to find out by psychophysical experiments how perception works in the reading process so one can reconstruct impartially intersubjective validated mental images produced by reading literay texts. It will be claimed that both in literature and cognitive science one is confrontated with subjective forms and ways of perception. Both disciplines describe how signals from the outside world are interpreted and constructed to a (readable) world (Heinz von Foerster). Where cognitive science accents the research of the processes inside the brain and how it forms by inherent structures in combination with given sense-data its 'reality', literature can focus on the act on how personal conceptions, ideas and associations are transformed in words and texts and how these verbal representations of perceptions interact, correspond or confront with the society and its historical and/or cultural different forms and norms of perception. So we think that perception is always also a social phenomenon as it is communicated and evaluated by language and other signs and signals and language can also—for good or bad—replace one's own perceptions. Both the brain and literature are so to say filter-tools that form and construct 'as-if-realities', but, following Bachtin and its concept of dialogical literature, literary texts boost ambiguities and polysemies where in contrast the biological perception-apparatus is inclined to establish a monological and unambigous reality. These claims will be undermined by the presentation of the results of psychophysical experiments in which we analyzed possible correspondences between individual receptions of a literary text.

Working Memory Maintenance Contributes to Long-Term Memory Formation: An EEG Study

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Using slow event-related potentials we investigated the neural activity associated with the relation between working memory maintenance and successful long-term memory formation. Therefore, participants performed a delayed-matching-to-sample task with letter strings and objects which was followed by a surprise long-term recognition test. During working memory maintenance slow event-related potentials showed differences between the stimulus categories with more negative potentials over the parietal and occipital cortex for objects and over the left frontal cortex for letter strings. For subsequently remembered stimuli they were more negative in both categories with the maximum negativity over those cortical areas which differentiated stimulus categories in general. The results support the assumption that working memory maintenance contributes to long-term memory formation. Furthermore, they suggest that subsequently remembered items are associated with stronger activation in stimulus-specific working memory.

Visual Cognition: Objects and Faces

Sex Matters When You Ask the Right Question: What Affects Eye Movements in Face Comparison Tasks?

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Knowing where people look in a face provides an objective insight onto the information entering the visual system and into the cognitive processes involved in face perception. Eye-tracking studies on face perception have mostly investigated observers' viewing behavior when studying single faces. However, in day-to-day situations, humans also compare faces or match a person's face to a photograph. During comparison, facial information remains visually accessible, freeing observers from time and encoding constraints [1]. Here, we recorded eye movements of human participants while they compared two faces presented simultaneously. We used (i) two different tasks (discrimination or categorization), and (ii) faces differing either in identity or in sex. In addition, we varied (iii) task difficulty, i.e. the similarity of the two faces in a pair. Eye movements to previously defined areas of interest (AOIs) on the faces were analyzed in terms of frequency, duration and the temporal pattern of fixations made. We found that the eyes were fixated most often in the discrimination tasks (37% of all fixations) but the nose in the categorization task (34.5%), while the total number of fixations increased with task difficulty. Faces differing in sex were more difficult to discriminate than faces differing in identity (63% versus 76% correct responses), which was also reflected in more fixations to face pairs differing in sex (14.4 versus 11.8 fixations per trial). With increasing task difficulty, fixations to only some AOIs increased, in accordance with the literature (more to the eyes in the sex and more over all areas in the identity discrimination tasks; [2]). Unexpectedly, we found a striking effect of tasks on performance measures, as over 80% of participants could detect the more feminine of two faces (categorization task) even at the most similar level, but for the same face pairs their performance in a discrimination task was less than 30% correct. Another interesting finding is that observers mostly compared the inner halves of the two faces of a pair, instead of the corresponding features (e.g., the left eye of the left face with the left eye of the right face). This viewing behavior remained the same in a control experiment where participants' head was not fixed. Quite surprisingly, female participants fixated significantly more often the eyes of the face stimuli than male participants, but only when the sex of the faces was a relevant feature in the task.

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Looking Down, Looking Up: Does Stature Influence Face Recognition?

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In the German population, men are on average 13 cm taller than women [1]. Smaller people, many of them women, look at other faces from below (viewing angle) while tall people look at others from above. The minimal distance between 2 persons not engaged in mutual gaze is around 50 cm [2]. Thus, with regard to male and female average statures, in close-up situations, the average viewing angle between males and females is around 13 deg. Do people have therefore different "preferred" representations of faces depending on their stature? More specifically, are tall and small people more efficient at processing face seen "from above" and from "below" respectively? Furthermore, do observers have different "preferred" representations of male and female faces because men are on average taller than women? To investigate the influence of stature and sex on face recognition, we first investigated whether efficiency in a sex classification task might be influenced by face orientation. To maximize stature differences between participants, we tested two groups: small women (under 165cm) and tall men (over 180cm). If face representation is influenced by stature, we expect small women to be more efficient (faster) at processing faces viewed as seen from below and vice-versa for tall men. Furthermore, because of natural average stature differences between men and women, efficient categorization of male and female faces might depend on their orientation. We used unfamiliar male and female faces shown at pitch angles between -18 deg (looking downward) to +18 deg (looking upward). We tested participants in a speeded sex classification task. Male and female participants saw 220 faces one by one and had to classify them as male or female as fast as possible. Classification accuracy was high (over 95%). Analysis of reaction times does not show any relation between stature of observer, sex of shown face and its pitch orientation, thus suggesting that face processing with regards to sex is not influenced predominantly by stature of observer or sex of presented face.

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Lighting Direction Affects Perceived Shape from Shading.

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It has been known for a long time that many cues contribute to the perception of 3D shape from 2D images, such as shape from shading, textures, occlusions or reflection of the surrounding environment. However, little is known about the influence of lighting conditions on the correct mental reconstruction of 3D shapes. In order to investigate this, we have run a set of experiments asking participants to report differences in surface orientation of unknown, smooth surfaces, using different methods. The first experiment consisted of a 2AFC in which subjects had to identify which of two test objects had the same shape as the target. The stimuli were computer generated irregularly-shaped smooth surfaces, illuminated by a single point light source. For both test stimuli, the position of the light sources could either be different from or the same as the target. Results show that, as the amount of shape difference became smaller, participants were more and more biased towards choosing the match shape lit by the same source as the target. In the second experiment, participants had to report the perceived orientation of the surfaces at various locations by adjusting gauge figures.. The surfaces could either be the same or slightly different and the light source of each shape could either be the same or offset by 90 degrees horizontally. Participants' matches revealed large differences in perceived surface orientations when the lighting was different, even when the shapes were the same, confirming the first results. Our findings show that lighting conditions can play a substantial role in the perception of 3D structure of objects from their 2D representation. We also discuss the implication of this in the domain of computer aided visualisation.

Perception of Dynamic Facial Expressions Probed by a New High-Level After-Effect

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High-level after-effects have been reported for the recognition of static faces [1,2]. It has been shown that the presentation of static 'anti-faces' biases the perception of neutral test faces temporarily towards the perception of specific identities. Recent studies have demonstrated high-level after-effects also for point-light walkers, resulting in shifts of perceived gender [3,4]. We present an experiment showing for the first time high-level after-effects in the recognition of dynamic facial expressions.

Facial expressions were generated as a morph animation based on a weighted sum of 3D shapes derived from scans of facial action units [5]. With this technique we were able to define a metric space of dynamic expressions by morphing, similar to face spaces for static stimuli. Morphing between prototypical expressions (happy and disgust) and a neutral face without intrinsic facial motion we generated 'anti-expressions' by choosing negative weights for the prototypes. In addition, for testing we generated expressions with reduced recognizability choosing small positive weights of the prototypes. The morphing space was equilibrated for recognizability by measuring the psychometric functions that map the morphing weights on the recognition rates of the two expressions (happy and disgust) in a 2 AFC task. Only the non-rigid intrinsic face motion was morphed. In addition, a meaningless 3D head motion was added in order to minimize the influence of low-level adaptation effects. Subjects were adapted for 8s with 5 repetitions of the anti-expressions. They were tested with happy and disgust expressions with reduced expression strength. Adaptation stimuli were simulated with 2 facial identities and were shown either in forward or reverse time order.

We found strong expression-related after-effects (increased and decreased recognition for matching and non-matching expression, respectively, $p < 0.05$, N=13). We investigated the influence of static vs. dynamic representations in the observed after-effect. The temporal order of the adapting stimuli does not have a significant influence on the strength of the observed after-effect. The analysis of the 2D optic flow patterns of adaptation and test stimuli rules out the possibility that the observed after-effects reflect classical low-level motion after effects. Instead, the results seem compatible with the adaptation of neural representations of 'snapshot keyframes' [6] that arise during the presentation of dynamic facial expressions.

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Perceptual Grouping in the Human Brain: Cue-Independent Processing of Global Shape

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The integration of individual features is a fundamental process for the intact perception of a global scene. Several different gestalt grouping principles such as similarity and proximity of local elements aid this process. Clinical research suggests that there may be a general mechanism involved in the integration of local elements leading to global gestalt perception. We investigated the cortical substrates underlying perceptual grouping in healthy subjects, with particular emphasis on whether a common neural mechanism could operate irrespective of the gestalt cue used to guide the process. In an event-related functional magnetic resonance imaging (fMRI) study we measured neural activity as subjects used either similarity or proximity cues to group local features of a stimulus into a global percept. A conjunction analysis revealed that gestalt grouping involves the angular gyrus and middle temporal gyrus, bilateral superior frontal cortex and anterior cingulate cortex. Activations were lateralized to the left hemisphere. Our findings are strongly consistent with clinical accounts that suggest a structure in the temporo-parietal region may aid the integration of local features into a global percept. Damage to this region of cortex results in simultanagnosia, a deficit associated with integrating multiple objects into a coherent visual scene.

Object-Context Interactions in Visual Natural Scene Processing with Respect to Orientation and Semantics: A MEG Study

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We investigated object-context interactions in the neuronal processing of natural scenes with regard to orientation and semantic content of the context. Furthermore, we tested whether possible orientation specific interactions are mediated by information in low or high spatial resolutions.

We recorded the magnetoencephalogram (MEG), while subjects performed a yes-no animal detection task. Photographs of natural scenes, containing a clearly identifiable object, were presented consecutively with a fixation marker for 1000 ms. 50 percent of the scenes contained an animal (target) and otherwise a non-animal object (non-target). The subject's task was to respond in order to discriminate the target from a non-target by a button press. Objects were always presented in upright orientation. Six experimental manipulations were applied to the scene contexts to investigate object-context interactions. We presented pictures of: A) Objects in upright intact scene contexts. B) Objects in 90° rotated intact contexts. C) Objects in 90° rotated contexts with information about scene content in low spatial resolutions. High spatial resolutions of the contexts were phase-randomized. D) Objects in 90° rotated contexts with information about scene content in high spatial resolutions. Low spatial resolutions were phase-randomized. E and F) Upright objects embedded in upright or 90° rotated meaningless phase-randomised contexts served as baseline conditions.

Significant effects of context manipulations were found in an early MEG-deflection around 170ms after scene onset in posterior sensors and after approximately 300ms in fronto-lateral sensors. The highest amplitudes in the 170ms deflection were obtained with objects in meaningless upright and meaningless 90° rotated contexts (no difference). The amplitude was significantly lower with objects in meaningful upright contexts. A further significant reduction was found with 90° rotated intact contexts. The amplitudes obtained with scene contexts carrying information in low spatial resolutions were similar to those obtained with meaningless contexts. However, similar to intact 90° rotated contexts, the rotated contexts with information about scene content in high spatial resolutions reduced the amplitude of the 170ms deflection. In the interval after 300ms the highest MEG-amplitudes where obtained with upright objects in upright intact contexts.

Our data suggest that both, a meaningful context and orientation incongruence between object and context have an inhibitory influence on early object specific processing reflected by the reduction of the 170ms deflection. Information in high spatial resolutions appears to cause the orientation effect. However, the increased fronto-lateral amplitudes found after 300ms with meaningful upright contexts indicate that memory representations are enhanced by these contexts.

A New Model for Learning Invariant Object Representations, Based on Spatio-Temporal Correlations and Self-Organizing Maps.

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Our visual system is capable of recognizing objects under different viewing angles, despite drastically different retinal images. We investigate whether the association of different views to the same object can be learned by exploiting temporal correlations because successive images in the same retinal region usually correspond to the same object. We present a new biologically plausible approach that combines temporal correlation-based invariance learning [1] with the concept of self-organizing maps (SOM) [2] to learn topographic maps of invariant object features. We propose that such a mechanism may underlie object feature maps in inferotemporal cortex [3].

Our model consists of a three-layer network of leaky integrate-and-fire neurons with biologically realistic conductances. Stimuli in the input layer are represented in the map layer via excitatory forward connections that exhibit Hebbian-like spike-timing dependent plasticity (STDP). Neurons within this layer are connected via short range lateral excitatory connections and lateral inhibition. We trained the network with stimuli varying along two dimensions, corresponding to viewing angle and object identity. Temporal correlations in the input mimicked natural viewing conditions where different views of the same visual object often occur in temporal succession.

After learning, each neuron in the map layer was selective for a small subset of the stimulus space. Stimuli which were temporally correlated during training tended to become represented close to each other. Thus, a representation emerged in which slowly varying stimulus features (object identity) were represented within localized regions in the layer, while the representations for stimulus features that varied on short time scales (viewing angle) showed a distributed, patchy pattern. As a consequence, neurons in the output layer with a localized receptive field in the map layer responded selectively for the slowly varying stimulus features, invariantly with respect to the other features.

In our model, temporal correlations are captured by the slow decaying dynamics of the NMDA current, which mediates the lateral excitatory connections. Temporal correlations between training stimuli lead to spatial proximity in the developing topographic map. It is conceivable that the development of object feature topography in the inferior temporal cortex may rely on similar mechanisms. Our model demonstrates how spatial and temporal correlations can be used together to learn invariant representations.

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Learning Affects the Spatial Frequency Content of Mental Representations for Dynamic Faces

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Using a delayed visual search paradigm, we showed that non-rigidly moving faces are better encoded than static faces [1]. In this task, observers learned one dynamic and one static face, and then searched for either target in a static search array. Here, we used high (HSF) and low (LSF) frequency filtered faces during visual search to investigate whether the behavioural difference lies in the mental representation of different spatial frequencies for dynamically and statically encoded faces. It is thought that high spatial frequencies mediate featural processing, whereas low spatial frequencies mediate configural processing [2]. In Experiment 1 (N=12), we used a learning procedure which only required observers to rate the targets along different character traits. We found no advantage for dynamically learned faces, but HSF faces were recognized more accurately ($p<.05$). In Experiment 2, we used our previous learning procedure which required observers to assess both targets' personality and facial features using a detailed questionnaire. Observers (N=8) were faster at finding dynamically-learned faces ($p<.05$), and showed an advantage for LSF faces ($p=0.07$). Taken together, these results show that the nature of learning can affect face encoding strategies. Furthermore, the frequency effects suggest that less familiar faces may be recognized more from features than from configural information.

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Left-Right Asymmetry of Emotionally Expressive Full-Body Movement

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The two sides of the human face differ in intensity of emotional expression. This effect is usually demonstrated using 'chimeric' pictures, with one hemiface replaced by the other's mirror image. Left-left chimeras are rated as more expressive than right-right chimeras [1], implying higher expressiveness of the left hemiface. This finding has been interpreted as supporting a dominant role for the right hemisphere in emotion. The asymmetry is sometimes reduced or even reversed for positive emotions, a finding consistent with the idea that emotion valence affects which brain hemisphere plays a dominant role. We investigated whether asymmetry of emotional expression extends to emotions expressed in full-body movement. Such a finding would imply that asymmetry of emotion expression represents a more general phenomenon than previously assumed, and make the asymmetry of facial emotion expression less likely to result from general, non-emotional hemifacial mobility differences [2].

We motion captured left- and right-handed individuals expressing anger, fear, happiness and sadness in walking. After computing joint angles, we compared amplitudes and kinetic energy between the left and right side of the body. In order to assess left-right differences in intensity of emotional expression, 'chimeric walkers' were created by animating an avatar with the joint movements of one body side replaced by those of the other, with appropriate temporal alignment. Observers rated the expressiveness of the original animations, and of right-right and left-left chimeras.

The left side of the body exceeded the right in movement amplitude and energy for all emotions, especially in upper-extremity movement. The direction of asymmetry was not reversed in left-handers, indicating that the movement asymmetry is not induced by higher movement amplitudes on the non-dominant side of the body. Higher expressiveness ratings for left-left than right-right walkers for all emotions except fear show that the movement of the left hemibody is also perceived as more intense in emotional expression, consistent with the right-hemisphere hypothesis of emotion. An influence of two usual possible confounds in studies with static chimeric faces, namely, anatomical or timing asymmetries between the left and right side, was excluded by using dynamic stimuli with symmetric anatomy.

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Using the Local Field Potential (LFP) Recorded from the Inferior-Temporal Cortex of a Macaque Monkey to Study Species-Dependent (Monkey/Human) Face Processing

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Recently, we have been able to read out a human/monkey face category-boundary from single-unit-activity (SUA) recorded from the inferior-temporal (IT) cortex of a macaque monkey brain. This data was collected in an experiment where monkeys have to fixate at pictures of human/monkey morphed faces at different levels of this 'species-continuum'. Consistent with our previous psychophysical experiments in which human subjects have to categorize morphed faces as humans or monkeys, the perceptual boundary seems to be shifted towards the 'own-species' category (approximately 60% human/40% monkey in humans and the other way around in the monkey data). Similar to the 'other-race' effect, this effect suggests a perceptual bias that could be due to long-term learning.

The local field potential (LFP) refers to the low-frequency (< 300Hz) component of signals recorded from the brain, and it has been associated with dendritic activity within a particular recording area. In this work we investigate to what extent these LFP signals are stimulus selective and weather they correlate with our previous results obtained from the simultaneously recorded spiking activity (SUA).To achieve that, we first extract different features from the LFP signals such peak amplitude, time-onset or the spectral power of different frequency bands. To evaluate the information content of these features in relation to our stimulus and the spiking data, we use statistical analyses, information theory and pattern classification.

Preliminary results show that features such as peak onset-time and peak-amplitude differ significantly across stimulus-conditions. In contrast to the spiking data, when using these features, the pattern classifiers set the face category-border without a consistent shift towards the monkey category. Further analysis of these features using information theory will be needed to test possible correlations with the spiking data and the stimulus properties.

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Physical Self-Motion Facilitates Object Recognition, but Does Not Enable View-Independence

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It is well known that people have difficulties in recognizing an object from novel views as compared to learned views, resulting in increased response times and/or errors. This so-called view-dependency has been confirmed by many studies. In the natural environment, however, there are two ways of changing views of an object: one is to rotate an object in front of a stationary observer (object-movement), the other is for the observer to move around a stationary object (observer-movement). Simons et al. [1] criticized previous studies in this regard and examined the difference between object- and observer-movement directly. As a result, Simons et al. reported the elimination of this view-dependency when novel views resulted from observer-movement, instead of object-movement. They suggest the contribution of extra-retinal (vestibular and proprioceptive) information to object recognition. Recently, however, Zhao et al. [2] reported that the observer's movement from one view to another only decreased view-dependency without fully eliminating it. Furthermore, even this effect vanished for rotations of 90° instead of 50°. The aim of the present study was to confirm the phenomenon in our virtual reality environment and to clarify the underlying mechanism further by using larger angles of view change (45°-180°, in 45° steps). Two experiments were conducted using an eMagin Z800 3D Visor head-mounted display that was tracked by 16 Vicon MX 13 motion capture cameras. Observers performed sequential-matching tasks. Five novel objects and five mirror-reversed versions of these objects were created by smoothing the edges of Shepard-Metzler's objects. A mirror-reflected version of the learned object was used as a distractor in Experiment 1 (N=13), whereas one of the other (i.e., not mirror-reversed) objects was randomly selected on each trial as a distractor in Experiment 2 (N=15). Test views of the objects were manipulated either by viewer or object movement. Both experiments showed a significant overall advantage of viewer movements over object movements. Note, however, that performance was still viewpoint-dependent. These results suggest an involvement of partially advantageous and cost-effective transformation mechanisms, but not a complete automatic spatial-updating mechanism as proposed by Simons et al. [1], when observers move.

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Visual Cognition: Space Perception and Navigation

Path Integration and Obstacle Avoidance: Design and Test of a Virtual Agent.

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One of the most essential performances in navigation is the determination of a position relative to some starting point and, as a result, the ability to return to this starting point, such as a nest. A widely used method enabling this is called path integration or dead reckoning. The underlying principle of path integration is the continuous measurement and combination of speeds and turning angles along the path. While moving through space, obstacles blocking the desired path must be avoided.

The amount of experimental data concerning path integration in arthropods and mammals is constantly growing. Various mathematical models have been developed, using a wide variety of approaches for combining movements and representing the position of places. However, it is still uncertain which model best describes the biological mechanism.

In this study a model of path integration, based on differential equations, and a model of obstacle avoidance have been developed and combined in a continuous attractor scheme. The study is inspired by the behaviour of desert ants, while encountering obstacles on the way to their nest or a feeding location. The walking behaviour of an agent was tested in a virtual environment with few or multiple objects (cluttered environment). The agent was capable of avoiding nearly every presented obstacle relying solely on real-time visual data.

Furthermore, different path integration strategies (using egocentric or geocentric and Cartesian or polar coordinate systems) and several types of noise models were used in a series of simulated triangle completion tasks. The Runge-Kutta-Fehlberg method was chosen for solving the path integration equations. From this study, predictions can be made concerning the homing errors resulting from different versions of the path integration algorithm and error model. Comparisons with psychophysical data are discussed.

Desert Ant Navigation in Cluttered Environments: Which Visual Features are Used?

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The recognition of locations is a common and important spatial behavior where an animal attempts to reach one or multiple target positions. It is amazing that insects have evolved effective solutions for this problem with a relative simple nervous system and restrictive processing capacity.

The Australian ant Melophorus bagoti navigates in an environment cluttered with small grass patches. If trained to revisit a feeder, each individual ant establishes habitual out- and inbound routes, that in many cases differ from each other [1].

To study this behavior, an artifical agent comprising panoramic vision, obstacle avoidance, and path integration was set in a virtual model of the ants' real environment. Using a combination of path integration and obstacle avoidance the agent could not reproduce most of the ants trails. Furthermore the sometimes considerable difference of outbound and inbound routes is not reproduced. This shows that local position information must be used by the ants to follow their individual routes.

The use of visual information in terms of snapshots has been shown for insects. But it is still unclear which features of an image are stored and used for relocating. In this study the use of skyline information versus the raw image information is examined. Panoramic images from the virtual environment and real world images were used for evaluation. Using a cross correlation the whole images and the panoramic elevation profiles (skyline) were compared. The skyline extraction leads to: i) highly data reduction ii) more unambiguous relocation iii) illumination invariance. Results from comparing images from the virtual environment provide evidence that the ant is able to distinguish different locations along and beside their habitual routes using skyline information.

In further studies visual memory, path integration and obstacle avoidance will be combined.

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The Effect of Goal-Knowledge Manipulation on Task Performance in a Cooperative Computerized Navigation Task

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Recent experiments suggest that goal-knowledge is a critical component in understanding the actions of others in joint-action settings involving humans and robots [1,2]. In the current experiment, we manipulated knowledge of a spatial end-goal in a computerized navigation task in which two jointly acting participants carried a bar through an obstacle course. In one condition, the spatial goal was visible to only one participant, while in the other condition the spatial goal was visible to both participants. We predicted that participants would perform better and be more coordinated when goal-knowledge was shared. Mean jerk and average duration of successful trials decreased across time for all conditions. Average duration of successful trials was shorter in the both know goal condition. However, the number of bar drops was significantly higher in the both know goal condition. Coupling between speed, acceleration and trajectory of co-actors was measured by calculating the correlation between these measures at different temporal latencies. This correlation increased over time, suggesting that coupling behaviour improved in general. Furthermore, these correlations were significantly higher in the both know goal condition. Cross-recurrence analysis [3] was used as additional measure of coupling between participants. These findings are discussed in terms of their relevance for understanding joint action in humans and robots.

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Human Route Learning in Virtual Cluttered Environments

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In this study, characteristics of human route learning in virtual, large, cluttered environments were investigated. Experiments were conducted using a desktop virtual environment depicting a plane with unevenly spaced columnar obstacles of uniform texture and height but different outline. To give a general compass direction, four global landmarks were added. This environment proved to be of appropriate difficulty to afford several training sessions, allowing a closer analysis of the learning process. Subjects had to find a way from a starting point to a target and back again, thereby choosing one of many alternative routes. The training took place on three to five consecutive days, depending on the subject's performance, with two sessions of 20 minutes per day. Analysis of the trajectories over sessions yielded a significant change of several parameters. As participants gained experience, overall run duration shortened. This was due to the participants taking routes of higher path efficiency while walking faster and making less orientational stops. However, there were strong individual differences concerning the strength of these changes, the degree of variance of the final routes and initial search patterns. Ten of eleven subjects were able to establish a route, with five participants using slightly varying trajectories, both within and across run directions (inbound / outbound). The remaining five subjects adopted constant routes which were identical for inbound and outbound directions in three subjects. In summary, results indicate that humans spontaneously form fixed or slightly varying routes in cluttered environments, which may differ for inbound and outbound directions.

Long-Term Memory for Environmental Spaces—The Case of Orientation Specificity

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This study examined orientation specificity in human long-term memory for environmental spaces, and was designed to disambiguate between three theories concerning the organisation of memory: reference direction theory [e.g., 1], view dependent theory [e.g., 2] and a theory assuming orientation-independency [e.g., 3]. Participants learned an immersive virtual environment by walking in one direction. The environment consisted of seven corridors within which target objects were located. In the testing phase, participants were teleported to different locations in the environment and were asked to identify their location and heading and then to point towards previously learned targets. In experiment 1 eighteen participants could see the whole corridor and were able to turn their head during the testing phase, whereas in experiment 2 visibility was limited and the twenty participants were asked to not turn their heads during pointing. Reference direction theory assumes a global reference direction underlying the memory of the whole layout and would predict better performance when oriented in the global reference direction. However, no support was found for the reference direction theory. Instead, as predicted by view-dependent theories, participants pointed more accurately when oriented in the direction in which they originally learned each corridor, even when visibility was limited to one meter for all orientations (all results $p<.05$). When the whole corridor was visible, participants also self-localised faster when oriented in the learned direction. In direct comparison participants pointed more accurately when facing the learned direction instead of the global reference direction. With the corridors visible they also self-localised faster. No support was found for an exclusive orientation-independent memory as performance was orientation-dependent with respect to the learned orientation. We propose a 'network of reference frames' theory which extends the view-dependent theory by stating how locations learned from different views are connected within a spatial network. This theory is able to integrate elements of the different theoretical positions.

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Gait Parameter Differences Within an HMD as Compared to the Real World

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It has been shown that virtual environment (VE) users make systematic errors of distance compression when acting on or judging a virtual space (blind-walking to targets on the ground plane or verbal reports [1,3]). This bias in behavior can, in part, be explained by the mechanics of the head-mounted display (HMD). Willemsen et al. [3] have developed a modified HMD in which the visual display has been removed and yet weight distribution is kept consistent with that of a functional HMD. When participants view the real world through this modified HMD they undershoot their blind-walking performance. Willemsen et al.'s research suggests that the weight or ergonomics of the HMD influences the distance traversed while performing a blind walking task [2].

In the current research, we consider four different conditions: walking with eyes closed within the real world, eyes closed wearing a HMD, eyes open in the real world, and eyes open wearing a HMD. By investigating these four conditions we can access whether there are differences in gait parameters due to the physical constraints of the HMD and/or due to the differences between the visual experience in the HMD and the real world. Full-body motion tracking data was collected for six participants while they walked to a previously seen target at 8 randomly ordered distances (3,4,5,6,7, 8, 9 and 10 meters).

We report three gait parameters for each of these four conditions: stride length, walking velocity, and head-trunk angle. This data reveals that these gait parameters within a HMD VE are different than those in the real world. A person wearing a HMD and backpack walks slower and takes a shorter stride length than they do in a comparable real world condition. In addition, head-trunk angle while walking to a target on the ground plane is lowest when walking with eyes open when wearing a HMD. While future research should investigate the influence of gait parameters on human perception of the active observer, the sole objective of the current research was to analyze the differences between gait parameters while walking within a HMD and the real world.

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Quality and Barrier-Effects in Pointing in Reality and in VR of "Kindergarten" Children and Primary School Beginners

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It is generally accepted that the possibility to orient and navigate in large scale urban areas develops, like all other intellectual capabilities, in the course of growing up. Uncertainty exists on the exact steps of that development and on the influence of individual experiences within that course. It may be possible too that there are critical time-windows in the child development in which experience is able to establish special knowledge. We performed 2 experiments, one with "kindergarten" children of the age of 5, and one with primary school beginners in the age of 8 in a large-scale urban environment that was unknown to both groups of experimental subjects. The task for the subjects was to point from different positions of the terrain towards a goal that was shown to them at beginning of the experiment. The test-points are positioned on free places in the terrain or near the walls of buildings. The experiment was performed twice. One takes place in the reality of our university campus, the other was performed in the VR "NeuViberg", a 180 degree visual field projection of a 3D representation of the campus with the possibility to navigate through the VR walking as a pedestrian using a treadmill. We asked the children which experiences they had in exploring their living neighbourhood for their own and whether they used to play computer games. They performed a paper pencil test to evaluate their spatial abilities. The results show for the 5 years old children a sometimes precise ability of pointing to the invisible goal in the reality. The results show a significant gender effect. Girls performed worse than boys do. The results for the 8 years old school children point in the same direction. The gender effect was not so clear but still existing. In both experiments we get no clear barrier-effect. The results of boys and girls of the experiments in the VR are worse. This is a hint that orientation and navigation in virtual realities need a higher degree of abstraction that is developing in later stages of growing.

Spatial Orientation in the Immediate Environment: How Can the Different Theories be Reconciled?

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Recently, there has been an increasing interest in theories about human spatial memory and orientation (see, e.g., [1] for a recent review). There is, however, an apparent conflict between many of those theories that yet needs to be resolved. Here, we outline a theoretical framework that aims at integrating two current theories of spatial orientation: May [2] proposed that the difficulty of imagined perspective switches is caused, at least in part, by an interference between the sensorimotor and the to-be-imagined perspectives. Riecke & von der Heyde [3] developed a theoretical framework that is based on a network of logical propositions (i.e., necessary and sufficient conditions). They proposed that automatic spatial updating can only occur if there is a consistency between the observer's concurrent egocentric reference frames (e.g., mediated by real world perception, virtual reality [VR], or imagined perspectives). We propose that the underlying processes are the same, in the sense that a consistency between egocentric representations [3] is equivalent to an absence of interference [2]. Whenever the current egocentric representations of the immediate surroundings are consistent, there should be no interference. According to [3], this state enables automatic spatial updating. We propose that this lack of interference might also be able to explain other important phenomena, such as the relative ease of adopting a new perspective after being disoriented. Conversely, interference (inconsistency) between the primary, embodied egocentric representation and a to-be-imagined (e.g., experimentally instructed) egocentric representation implies the difficulty of adopting a new perspective. We posit that such interference or inconsistency also explains the difficulty people have in ignoring bodily rotations. To avoid the vagueness that purely verbally defined theories sometimes suffer from, we offer a well-defined graphical and structural representation of our framework. Integrating logical and information flow representations in one coherent framework not only provides a unified representation of previously seemingly isolated findings and theories, but also fosters a deeper understanding of the underlying processes and enables clear, testable predictions.

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Behavioural and Electrophysiological Studies in Virtual Environments

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By using a newly developed virtual reality (V.R.) setup a variety of experiments have been performed to demonstrate the applicability of this method (for a detailed description of the setup see [1]). Preceding experiments have shown that the animals are able to interact with the virtual environments that where presented to them (see also [1]). The more recent experiments were designed to demonstrate that the animals can also perform spatial tasks within a virtual environment. On a purely behavioural basis an experiment was designed that bases on the paradigm of the Morris-Water-maze experiments. In order to adopt this task in V.R., a 20 by 20 m squared environment was created with a rewarded area in the centre of one quadrant. The walls of this arena where textured with different patterns to make them distinguishable. By starting from the centre of the environment, the animals learned to approach a visually marked rewarding area reliably. The diameter of this visual cue was then stepwise reduced until it was finally removed. By this time the animals had to orient themselves at the distinct landmarks, e.g. walls. In a final testing trial the reward area was also removed. The data show that the animals predominantly searched in the formerly rewarded quadrant. Another approach to investigate above mentioned question is realised in a pilot study which revealed the applicability of electrophysiological cell recordings in combination with our virtual reality set-up. To ensure that the animals repeatedly visit the same position in the large environment that was used, which is crucial to examine the correlations between position and firing, the animals were trained to run on a ring-shaped road. This road had a diameter of 5 m and was placed in the centre of a 20 m by 20 m squared environment. In a small number of animals typical hippocampal place cells could be identified, responding to certain places in the virtual environment. A second branch of current experiments was designed to reveal the necessary physical properties of a virtual environment to become perceived by the animals. In this case standard discrimination tasks being performed, in which two targets with different physical properties had to be discriminated. First data were evaluated regarding the required brightness and contrast values to be used for the design of further experiments. In summary this results make clear that virtual reality technique gives us a potent tool at hand to further investigate spatial behaviour in rats.

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Is There an Interaction of Path Integration and Cognitive Maps?

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INTRODUCTION: In general it is assumed that distances and bearing between different locations were memorized in a cognitive map. Furthermore it is accepted that path integration leads to the computation of a home vector, indicating the distances and bearing towards a starting location. Is there an interaction between these two different mechanisms to memorize metric attributes? Can path integration improve the accuracy of metric information in a cognitive map? We have investigated exactly this question with human subjects in a triangle completion paradigm. METHOD: We designed a virtual environment, consisting of two areas. The outer area serves as framework and was build by a skyline, a village, a beach and a forest. In the inner area were three (exp. 1) or five (exp. 2) objects arranged in an irregular fashion. Subjects were guided passively through the environment, from one object location to the next. After translating between three objects (two paths) they had to indicate the bearing of their starting location by moving a joystick in the corresponding direction. The next passive transportation started at this pointing location and so on and so forth. In the end subjects visited all objects in subsequent rounds. All in all they performed twenty rounds and ten pointing tasks. RESULTS: Both experiments (with 3 and 5 objects) have been performed with 10 male subjects. The results showed a learning curve for the pointing error for experiment 1 (3 objects). There was no learning curve for experiment 2 (5 objects). DISCUSSION: The reduction of the pointing error indicates learning and can't be explained by assuming path integration as underlying mechanism for this task. We propose an interaction of path integration and the cognitive map. So far it is unclear why this results hold for experiment 1 with 3 objects but not for experiment 2 with 5 objects. At the present we are replicating experiment 2 with additional feedback, to improve the performance of the subjects.

SFB 550

Development of a Joint Body in a Transportation Task and Its Aftereffects.

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Coordinating our actions with those of others is a fundamental task in every day life and yet the process of its initiation, development, and termination remains relatively unexplored. While it is generally agreed upon that humans require a certain period of time to establish a well-functioning joint action behavior, it is an open question whether humans can switch back to individual behavior instantaneously. In our experiment we investigated the coordination parameters in the transition from individual behavior to joint action behavior and vice versa.

We employed a large-scale (18x13m), immersive VR environment in which two subjects, equipped with head-mounted-displays and wireless connected laptops, can be tracked simultaneously (VICON tracking system) and interact with each other and additional objects. In this behavioral experiment two subjects were instructed to walkthrough a dynamically generated maze without colliding with the walls.

In the first condition (Baseline Condition) subjects walked through the maze individually (20 min). In the second condition (Joint Action Condition) subjects had to transport a stretcher (length=2.5m) through the maze together (40 min). In the final condition (Follow Condition) the stretcher was simply removed, and the subject continued walking (10 min) while remaining a constant distance of 2.5m. Between the first and second condition subjects received a 15 minute break; however between the second and third no pause was made since the immediate aftereffects of the second condition were to be measured in the third condition. Path characteristics were specified by a) path length around each corner, b) the minimal distance to the corner, and c) a symmetry parameter which determines how much a subject's path deviates from an ideal, symmetric track.

Compared to the Baseline Condition, participants in the Joint Action Condition increased as expected their path length and their individual distance to the corner, and deviated from a symmetric path due to the extended physical boundaries. Furthermore, all three path characteristics in the Follow Condition showed greater similarities to the Joint Action than to the Baseline Condition. Even without the necessity for cooperation subjects continued to exhibit a behavior similar to the Joint Action Condition. This effect can be interpreted as an aftereffect to the adaptation of the subjects to the joint task, in which compensation was developed gradually. After prolonged joint action participation, subjects require a particular amount of time or exercise to return to independent walking behavior.

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Visual Perception: Colour

The Dynamical Properties of the Neon-Spreading Effect

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When a small red cross is aligned with the four black inducers of the Ehrenstein figure, a disk-shaped veil of red colour fills-in the central gap (neon colour effect). A growing body of literature now has started to unravel the conditions which yield the maximum effect, however the temporal properties of the effect, despite being just as informative, have been largely overlooked. To this aim we presented subject with sequences where the black inducers and the red cross (0.3° wide, 10° and 2° long respectively) had different onset time and different exposure durations. Subjects rated the strength of neon colour. We found: (i) an inverted U-shaped curve when a brief (48 ms) red cross was flashed at various SOA's relative to the black Ehrenstein figure (600 ms). In other words when the red cross roughly onset or offset together with the black figure, the effect was strongest. (ii) a ramp-shaped curve when the black inducers were briefly flashed relative to a prolonged red cross; the later the inducers the stronger effect. On the top of this effect, we found again that a very strong neon spreading occurred when cross and inducers offset or onset together. At a closer look we found that the "onset together peak" occurred at SOA 0ms so, as far as neon colour is concerned, information about the red cross and black inducers have the same latency. On the other hand a closer look at the "offset together peak" revealed that the information about the red cross reverberated in the system even after the red cross had offset. Overall we found that transient activity does not only result in perceiving the onset and the offset of the stimuli but also into the strength of the perceived neon colour. This is an example of how the world we see is not only an ongoing representation of what our receptors capture but also a collection of the most recent changes which we sensed.

The Importance of Color in Object Recognition

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Color is a salient feature which conveys important information about the objects in our visual world and may help identification and recognition. Previous psychophysical experiments in humans suggest that color can be beneficial in visual memory tasks, when shape information is no longer available. Here, we ask whether color in natural scenes improves object recognition under conditions in which shape information is degraded. We used a procedure based on Fourier analysis to create natural scenes, for which we manipulated color and shape information independently. Psychophysical performance of human observers was measured in a delayed matching to sample paradigm. Our observers were presented with natural scenes that contained object related (color image), irrelevant (colored noise) or no color (achromatic image and noise) for which we parametrically varied shape information by introducing noise into the images. Subjects performed significantly better when images contained object related color than no or irrelevant color information across the different noise levels ($N = 8$, $p<0.05$). In addition, performance across subjects did not differ for the achromatic stimuli and the images including unrelated color. Our results suggest that recognition of natural scenes can be enhanced by color information that is related to the object.

Unique Hue Shifts Induced by Background Color. How Color Induction Influences the Perception of Unique Hues

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In a previous study we investigated how the hue of a stimulus is influenced by the hue of an inducing background. Expressing hue as azimuth angle in cone-opponent color space, we measured color induction as a function of hue differences between stimulus and surround, using an asymmetric matching task [1]. Here we tested whether color induction is task-dependent and measured the influence of surround hue on unique hue settings. Subjects performed unique hue settings by adjusting the hue of 2-degree chromatic patches presented on isoluminant backgrounds of different chromaticities. In the baseline condition the background was neutral gray, in the test conditions the background had a chromaticity corresponding to one of eight hue angles with fixed cone contrast with respect to the gray background. Settings for unique hues on the gray background were in agreement with the well-known distributions of unique hues along the azimuth angle of cone-opponent color space [2,3]. However, on colored backgrounds, unique hue settings differed systematically from these angles, depending on the hue of the background. When plotted as a function of hue angle difference between the baseline settings and background hue angle, induced unique hue angle shifts showed a maximum around 70 degrees, with maximal induced shifts of about 23 degrees. Qualitatively, induced hue angle changes were similar to those in our pevious study obtained using asymmetric matching. In both studies percieved hues were shifted away from the chromatic angle of the inducing background and the amount of induced hue change depended on the hue angle of the background. However, we found quantitative differences between the results of both studies. While the observed shifts were largest along a red-green axis and smallest along a blue-yellow axis in the asymmetric matching task, we found the opposite for the unique hue setting task. This may indicate a special role of the unique hues for judging color appearance.

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Enhanced Selectivity for Natural Image Color in V4 but Not PF

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Color in natural images adds a perceptual dimension which may facilitate object identification. Here we investigate whether color in natural images leads to changes in visual memory performance in the primate and study the neural basis of this effect in extrastriate area V4 and dorsolateral prefrontal cortex (PF). We used a procedure based on Fourier analysis to create colored and achromatic natural images as well as control patterns that carried no task specific information. We employed a delayed matching to sample paradigm: a sample stimulus (250ms) was presented followed by a probe stimulus (1s) after a delay period (1500ms). A lever press was required if the sample stimulus matched the probe. Monkeys' recognition performance was near ceiling for both chromatic and achromatic natural images, and at chance for both kinds of control patterns. We have single neuron responses from a total of 84 neurons in V4 and 62 neurons in PF recorded from two monkeys. In V4 the majority of visually responsive units showed greater selectivity for chromatic than achromatic natural images in both monkeys (paired t-test $p<0.005$ N=32, $p<0.05$, N=20). Selectivity to natural images was greater than that for control patterns, for which we also observed no chromaticity-dependent difference in selectivity. Our findings reveal functional specialization in processing natural image color in V4, which appears to be absent in PF cortex.

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Quantitative Evaluation of Changes in Color Perception Due to Sunglare Protection Filters

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Sun glasses reduce the power of the incoming light unequally across the spectrum. The relative attenuation of the spectral light and its impact on color perception are conventionally assessed by Q factors describing the attenuation of red, yellow, green and blue signals (European Standard EN 1836). Besides their complicated calculation Q factor values are obviously arbitrary and hence fail to accurately represent the observed distortions in the appearance of natural colors [1]. Based on Wolter's classic concept of "normal colors" [2–4] (metrically represented by ellipses in color space) an alternative approach of evaluating filter-induced color changes is developed by transformations of normal colors. Only three parameters (shape, position and tilt of the ellipse in color space) are sufficient to comprehensively describe these color changes. Compared to the conventional approach based on determining Q factors the present method allows easier and more precise prediction of how a given filter will influence color vision. Moreover, the conclusive evidence of color changes afforded by transformations of Wolter ellipses recommend their use as a feasible alternative to comparatively evaluate the color vision quality of sunglare protection filters.

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Visual Perception: Eye Movements

Topography of Saccadic Suppression

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It is known for many years now that vision is suppressed during saccadic eye movements. Contrast thresholds for the detection of visual stimuli are significantly increased briefly before, during and after saccades. Previous studies measured the temporal evolution of the suppression but did not investigate any location dependency. Accordingly, in our current study we explored the contrast threshold for visual stimuli presented during saccades at different positions in the visual field.

Eye movements were recorded in human subjects with an infrared eye tracker (EyeLink 2, SR-Research) running at 500 Hz. Visual stimuli (patches with a 2-D gaussian luminance profile) were displayed on a homogenous grey background. The subject's head was supported by a chin rest. In different sessions subjects performed either control or eye movement tasks. In the control task the subjects fixated a target at [x, y]=[-7.5°, 0°], i.e. left from the center on the horizontal meridian (HM). In the eye movement trials, subjects performed 15° saccades along the HM, i.e. from [x, y]=[-7.5°, 0] to [x, y]=[+7.5°, 0]. During fixation or briefly before, during or after the saccade, the visual stimulus was flashed at one of five different positions on the horizontal meridian, ranging from 15° left from the center to 12.5° right from the center. Across trials, we varied the luminance of the stimulus leading to Michelson contrasts between 2% and 48%. Subjects had to report whether they had detected a flash. A psychometric function was fitted to the data, the 50% threshold was taken for further analysis.

Contrast thresholds during fixation revealed only a slight dependency on retinal eccentricity. 50% thresholds ranged from 6% near the fovea to 10% at 12.5° retinal eccentricity. Confirming previous results, we found a dramatic increase of contrast threshold during saccades. This increase, however, was not constant across the visual field but rather increased systematically from locations near the fovea towards the retinal periphery. Compared to fixation the para-foveal threshold increased by a factor of about two, while thresholds at 15° retinal eccentricity increased by a factor of about four.

Our results clearly demonstrate a position-dependency of peri-saccadic contrast threshold. Our findings might stimulate further physiological and modeling studies aiming to determine the neural basis of saccadic suppression which is currently unknown.

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Eye Movements and the Use of Local and Global Landmarks

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INTRODUCTION: In visual navigation landmarks are an important concept to support different behaviors. Steck & Mallot [1] found that human subjects use both, local and global landmark information in a wayfinding task where it was necessary to associate certain movement vectors to both types of landmarks. The paradigm allowed it to conclude which type of landmark a subject used for a certain movement decision. Here we investigated if there is an additional link to eye movements, which could be shown already for a couple of behaviors, i.e. tea or sandwich making [2]. With this method one would have a valueable tool to reveal the usage of landmarks by humans. Our hypotheses was, that landmarks, which are used for a movement decision are fixated more frequent and in particular are fixated just before the decision. METHOD: The experiment was performed in a virtual environment, called hexatown, consisting of a regular hexagonal grid of streets, junctions and landmarks. The wayfinding task was divided into two training phases and two test phases. In training I the participants should randomly explore hexatown and find the shortest way between two goals (office and home). In training II the participants were beamed to a junction and had to decide, left or right, where home or office have been. They get a feedback if the answer was wrong or right. The tests had the same procedure like training II but without feedback. In the first test we checked the performance of the subjects. In a second test the positions of the global landmarks have been switched, therefore we could conclude if subjects used local or global landmarks for wayfinding. RESULT: 16 participants were tested, but only 14 are analysed, because two of them reported the switch of the landmarks. Our results confirmed S. Steck's results that both types of landmarks are used to the same amount. But we did not found a correlation of the fixation frequency to the ongoing usage of landmarks.

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Localization of Visual Targets During Optokinetic Afternystagmus (OKAN)

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Spatial mislocalization of briefly flashed visual targets during voluntary eye-movements (saccades and pursuit) is a well described phenomenon. Yet, localization errors during reflexive eye movements (OKN) have been demonstrated only recently [1,2]. During optokinetic stimulation a moving textured background is permanently visible. This visual cue in itself might contribute to the observed localization errors. In our present study we therefore investigated localization during optokinetic afternystagmus (OKAN). OKAN is observed in total darkness in subjects who had previously performed an OKN. Hence, measuring localization during OKAN allows to dissociate between visually induced and eye-movement induced effects on localization. Four human subjects with normal or corrected to normal vision participated in the experiments. The subjects' head was supported by a chin rest. Eye movements were sampled at 500 Hz with an infrared eye tracker (EyeLink2, SR-Research). Visual stimuli were projected onto a tangent screen subtending $80^\circ \times 60^\circ$ of visual angle. In different sessions subjects performed either control or eye movement tasks. In control trials subjects freely viewed a white screen for 3000ms. Thereafter the screen turned black. 2500ms after this luminance change a target (white circle, 0.5° in diameter) was flashed for 10ms at one of three possible positions (-8°, 0°, +8°) on the horizontal meridian. In the eye-movement condition an OKAN was induced by moving a random dot pattern at v=80°/s across a white background for 15 seconds and turning the screen black thereafter. The target was flashed between 2500 and 4500 ms after this luminance change. In each case (control or eye movement condition) a ruler was presented 500ms after target presentation and subjects had to indicate perceived location with respect to this ruler. Localization during free viewing was not veridical: perceived target eccentricity was overestimated. When correcting for this baseline error, localization during OKAN slow-phase was (i) not shifted in the direction of the eye movement and (ii) dependent on retinal eccentricity. These results are dramatically different from what we previously reported for localization during OKN. Similar to the OKN condition, however, was a position-independent biphasic modulation of the perceptual error around the fast phases of the OKAN. Our results suggest that, similar to voluntarily controlled saccades, the availability of visual cues massively influences the pattern of localization of visual stimuli briefly flashed during slow reflexive eye movements.

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Eye Movements and Landmark Saliency in a Homing Task

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Recent experiments showed a tight link between eye movements and ongoing behavior for everyday activities as tea or sandwich making [1]. In our current experiment we have investigated this interaction in a navigation task. We used a homing paradigm where subjects were asked to find back to certain locations determined by surrounding objects. If an object is memorized for the purpose of navigation it is called a landmark. We investigated if it is possible to visualize this landmark usage by measuring eye movements and compare this method with a memory test and the homing accuracy. We measured eye movements of human subjects in a virtual environment, seated in front of a wide-field (150 x 70 deg) projection screen. So far 4 subjects were trained to find back to 5 locations defined by three surrounding objects. As dependant variable we measured the homing accuracy to the former trained locations. In the last trial we removed one object in the vicinity of the goal. Further we determined the saliency of each object in two ways: (i) by the recall rate in a memory test and (ii) by the number of fixations in the training phase. Our hypothesis was that the removing of objects with a higher saliency should lead to larger homing errors. We found no correlation for the memory test and the number of fixations in the homing task, indicating that our two methods to determine the saliency of a landmark differ. But there was a tendency that the homing error correlated with number of fixations towards the removed object. If our results will be confirmed with more subjects, we found a method to identify and define landmarks and the saliency of landmarks in a virtual scene.

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SFB 550

Visual Perception: Motion

Differential Coherency Dependency in Subregions of the Human MT+ Complex

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A functional hallmark of cortical neurons sensitive to visual motion is the dependency of their firing rate on motion strength. Specifically, single unit activity in macaque areas MT and MST is known to monotonically increase with motion strength such as motion coherence defined by the percentage of dot elements of a random dot kinematogram (RDK) moving in the same direction. Despite the strong similarities of the visual cortex of human and nonhuman primates, human area MT+, located in the posterior part of the inferior temporal sulcus (pITS) and probably comprising both areas MT and MST, has not consistently been found to respond stronger to coherent as compared to incoherent motion. A first goal of the present functional MRI study was to assess the responses to coherent and incoherent visual motion for both areas, separately. To this end, we exploited the fact that area MST lays immediately anterior to area MT and that only the first receives signals from both visual hemifields. A second goal was to test the influence of stimulus size. Blood oxygenation level depend (BOLD) responses were obtained from eleven human subjects who observed a RDK (stationary dots, incoherent motion, or coherent motion) in the right visual hemifield during stationary fixation. For a fixed eccentricity the stimulus extensions were varied in such a way to cover an area either equaling, exceeding, or falling below the mean MT receptive field size of macaque area MT [1]. Unlike the posterior part of left-hemisphere pITS, the anterior part and its right-hemisphere homolog showed significantly stronger responses to coherent as compared to incoherent motion. These differences were only present for stimuli larger than the estimated MT receptive field size. Based on these findings, we suggest that functional MRI may reveal stronger responses to coherent visual motion in human area MST provided that the stimulus allows for sufficient summation within the receptive fields. In contrast fMRI may fail to reveal the same dependency for area MT.

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The Motion After-Effect in Action and Perception

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After prolonged viewing of a unidirectionally moving stimulus, an apparent movement of a stationary stimulus can be observed in the opposite direction. This phenomenon is also known as the waterfall illusion. We initially tried to replicate the psychophysical well-known data regarding the motion after-effect (MAE). Subsequently, we asked whether the MAE modifies exclusively motion perception or, alternatively, also modifies the generation of goal directed actions, i.e. the initiation of smooth pursuit eye movements. In three healthy human subjects, we determined the amount of MAE. We used dynamic random dot kinematograms (RDK) with a single dot life time of 200ms to adapt for either 2 or 4s. Thereafter, a stationary or slowly moving RDK was shown for 200ms and subjects had to judge its direction of motion. In addition, we recorded eye movements by infrared eye tracking (IRIS Skalar) in a different experiment. After adaptation, a small target moved at 16°/s either in same or opposite direction and subjects were asked to pursue as precisely and fast as possible. In both experiments, subjects were instructed to keep fixation on a central red dot during motion adaptation. In accordance with earlier findings by others, the adaptation stimulus affected subjects' choices away from the adaptation direction. Adaptation durations as short as 2s produced a shift in the point of subjective stationarity (PSS) in the order of $\sim$0.25°/s, adaptation of 4s produced a more pronounced shift of the PSS of $\sim$0.3°/s. In addition, we found that pursuit onset latencies for pursuit targets moving in the same direction as the adaptation stimulus were significantly larger (mean 171ms, SD 42ms) than for pursuit targets moving in the opposite direction as the adaptation stimulus (mean 163ms, SD 44ms) (n=993, F=8.21, p=0.0043, ANOVA). This effect became most clearly visible in each of the three subjects when comparing median velocity profiles for adaptation in same and opposite direction, respectively. The two profiles are profoundly time shifted during the open loop phase, showing the later onset of the 'same direction' condition. However the initial saccade latency and the steady state 'closed-loop' gain did not differ depending on adaptation condition. We conclude that the visual MAE is able to influence motion perception as well as the generation of a motor response in a very similar fashion. With respect to motion processing, there seems to be no necessity to assume separate systems underlying perception and action.

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Radial Flow Perception at Different Light Levels

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Several studies have been concerned with changes in visual performance under low light levels, i.e. reduced performance due to the shift from cone- to rod dominated photoreception. Most studies focused on aspects like color vision, contrast sensitivity, or visual acuity. Only few studies investigated motion perception [1, 2]. The purpose of our study was to evaluate the effect of different light levels on the perception of radial flow. Radial flow represents a highly relevant form of motion information for navigation through our environment and its perception might be affected by spatial pooling at low light levels. The radial flow stimulus consisted of 100 white dots on a black background in a wide field expansion. A certain percentage of dots expanded coherently whereas the rest moved randomly. Focus of expansion (FOE) was shifted horizontally either to the right or to the left of the center of the field. Speed of expansion increased linearly from the FOE. Maximum speed was set to either 9.3 °/s, 18.6 °/s, or 37.2 °/s. Luminance was manipulated by filters resulting in photopic (98.5 cd/m2), mesopic (284.5 mcd/m2), and scotopic (18.0 mcd/m2) light levels. In a 2-alternative-forced-choice paradigm subjects had to detect the direction of heading. The percentage of signal and noise dots in the kinematograms was varied and thresholds were estimated by fitting the percentage of correct answers with a logistic psychometric function. A total of 6 naive subjects (3 females) with a mean age of 23.0 years (SD = 2.3), participated in our study. All observers had normal or adjusted-to-normal visual acuity. Results revealed significant effects of velocity and light level on perception of radial flow. In general, higher speeds of expansion were associated with lower thresholds. However, in all velocity conditions thresholds increased with decreasing luminance. The most pronounced effect was found between photopic and mesopic light levels. Thresholds at mesopic and scotopic light levels did not differ significantly. Thresholds at the photopic, mesopic, and scotopic light levels were 16.2%, 27.7%, and 26.6% in the low velocity condition, 8.3%, 18.0% and 20.1% in the medium velocity condition, and 5.0%, 9.1%, and 10.9% in the high velocity condition. Results for single observers mirrored the group results. Our findings indicate that radial flow perception is impaired under dim-light conditions. Changes in spatial pooling at low light levels might interfere with spatial-temporal analysis of wide field expansion.

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The Contribution of the Visual Scene to Disambiguation of Optic Flow with Vestibular Signals

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Optic flow is generated by observer motion relative to stationary objects, by movement of objects relative to a stationary observer, and by combinations of those situations. To determine the relative contributions of object and self motion to the observed optic flow, the nervous system can use vestibular signals. An object's speed relative to earth is given by the difference between its speed relative to the head and the head's speed relative to the earth. The variance of the difference is the sum of the component variances. In contrast, if observers estimate self-motion from optic flow and vestibular signals, and assume a stationary visual scene, visual and vestibular estimates may be combined in a weighted average to yield more precise self-motion estimates. So depending on whether the subject reports object motion or self-motion, the two-modality variance is predicted to be respectively higher or lower than the component variances. To test these predictions and the influence of the visual scene upon them, we measured speed-discrimination thresholds for fore-aft translations. There were two single-modality conditions, Visual and Vestibular, and two multi-modality conditions, Self-motion and Object motion. In the Visual, Vestibular, and Self-motion conditions, observers indicated if the movement was faster or slower than a standard. In the Object-motion condition, observers indicated if the object appeared to move with or against the self-motion. The experiment was run for two visual scenes, random-dots and ground plane with columns. In both scenes, multi-modal object-motion thresholds were, as predicted, higher than single-modality thresholds, and multi-modal self-motion thresholds were, as predicted, generally lower than single- modality thresholds. For the ground plane scene, the self-motion thresholds could be consistently predicted by the weighted average of the single modalities, which was not the case for the random-dots condition.

The Visual and Vestibular Perception of Passive Self-Rotation

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This study investigated human sensitivity to detect conflicts between visual and vestibular information about angular displacement during passive rotations around the earth-vertical (yaw) axis. During a passive whole-body rotation primarily the optic flow and displacement information from the visual system and the signals from the semicircular canals in the vestibular system play a role [1]. In our experiments, physical yaw rotations were presented using a Stewart Motion Platform and visual stimuli were shown on a projection screen. The gain (vis./vest.) – ratio between the visual and physical rotation angle—was varied so that the visual stimuli were either faster or slower than the physical rotation. The task was a psychophysical conflict detection task (2AFC) where different gain factors (0.25–2.75) of the visual and vestibular rotation speed were presented in a pseudo-random order and participants had to judge whether the visual motion was faster or slower than the real physical motion. The rotation angle of the platform was always 30° and a raised cosine velocity profile was used. Two different kinds of visual stimuli were used to compare the impact of visually rich and immersive visual stimuli ("Market place of Virtual Tuebingen (VT)") to that of a simple, abstract visual stimuli ("Limited life-time Random Dots (RD)"). The results show following effects. First, the psychometric function shows that the PSE (Point of Subjective Equality) is around the gain factor 1.6 (Vis./Vest.) across all subjects. This implies an underestimation of the visual speed: The visuals had to be 1.6 times faster than the physical motion to be perceived as equally fast. This is consistent with other studies which also show that there is an underestimation of the visual rotation speed [2, 3] in similar experimental conflict situations. Secondly, there is no significant difference of the PSE and JND (Just Noticeable Difference) between the VT- and RD-condition which could imply that the visual richness is not a significant factor to detect a conflict between the visual and vestibular inputs. Further control studies will be conducted to investigate whether different angular displacements and higher physical rotation speed will influence the PSE and the thresholds.

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The Intentional Goal of a Perceptual Task is Crucial for Activating the Mirror Neuron System—Not a Biological Movement Trajectory as Such

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The human mirror-neuron system (MNS) is assumed to be specialized for processing information about human actions either when these are performed or observed. Originally it was claimed that the MNS is activated exclusively by actions that belong to the motor repertoire of an observer. However, in a recent functional magnetic resonance imaging (fMRI) study we found strongly overlapping activation patterns including areas of the MNS when participants observed either non-biological artificial object movements or real hand movements. This suggests similar processes for perceiving hand and object movements. Furthermore, it implies that observing artificial non-biological object movements can activate the human MNS, either because they are spontaneously understood as biological or even as hand movements. However, the question arises, whether it is the intentional goal of an observation or just a special visual feature, like a smooth movement trajectory, that is crucial for the specific activation pattern in the MNS. To answer this question we performed a fMRI study with 20 participants. In a factorial design we contrasted two types of artificial object movements and two tasks. Three colored artificial objects followed either a smooth or a discontinuous velocity profile (factor "movement trajectory") and participants had to detect either whether the color of two attended objects changed during the movement (color task), or they had to rate whether the movement pattern of two attended objects could be imitated with the hands (simulation task). We found stronger activity in the MNS during the simulation than during the color task in the areas of the MNS, namely the left ventral premotor area and the left inferior parietal lobe, as well as in other areas (e.g., right superior parietal lobe, left posterior superior temporal sulcus). In contrast, the color task revealed stronger activity in the left ventral-occipital area (human V4), which is known for color processing. Most strikingly, there appeared no significant differences within the MNS for the two different movement trajectories. These findings suggest that it is the perceptual task which activates structures of the MNS and not a specific movement trajectory. This means that activity in the MNS seems to be modulated by top-down processing strategies that specify the intentional goal of a perceptual episode.

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Attention Modulates Low Frequency Oscillations Reflecting Signal-To-Noise Characteristics in a Visual Motion Discrimination Task

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Attention improves visual discrimination and consequently allows to discern stimuli with low signal-to-noise ratios that otherwise would remain undetected. In order to explain how attention improves motion perception the idea was put forward that attention enhances the neural signal-to-noise ratio. We used magnetoencephalography (MEG) to test whether low frequency oscillations recorded from occipito-temporal cortex and reflecting the size of visual motion signals embedded in noise (motion coherence) would mirror the perceptual changes induced by attention. To this end, we resorted to a motion discrimination paradigm for which we have recently observed a strong correlation between spectral amplitudes in a slow oscillating frequency band and the strength of visual motion varied experimentally by the coherence of a random dot kinematogram (RDK; Ref.1). In the present experiment attention was directed to one of two RDKs presented simultaneously left and right, respectively, from a central fixation point. Motion coherence could vary between 5%, 20%, 50%, and 100%, and was identical for the two RDKs in a given trial. In 80% of the trials subjects (n=7) had to detect the global motion direction of the cued RDK whereas in 20% of trials motion direction had to be indicated for the uncued RDK. A significant difference in perceptual thresholds for the cued (22% motion coherence) compared to the uncued RDK (44%) revealed that the subjects indeed followed the attentional instruction. Spectral amplitudes of a 3 ($\pm$2) Hz oscillation obtained from sensors lying contralateral to the attended RDK showed a clear dependency on motion coherence. Interestingly, no such modulation reached significance in sensors located ipsilateral to the unattended RDK despite identical stimulus parameters. We conclude that spatial attention directed to a given hemifield increases and decreases the coherence modulation of slow frequency amplitudes over contralateral and ipsilateral visual cortex, respectively, indicating a change in the neuronal signal-to-noise ratio matching the altered percept induced by attention.

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Multiple Images in Flickering Moving Lines: The Role of Pursuit Eye Movements

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Presenting a moving object on a monitor requires the display of an image sequence containing continuously changing object positions. The monitor showing the image sequence is refreshed at video refresh rates, e.g. 60Hz, which determines the number of potentially different images displayed to the user per second. The graphics program drawing the objects works at its own speed, which can be lower than the video refresh rate depending on the complexity of the objects drawn. This application frame rate is commonly an integer fraction of the video refresh rate and synched to the video refresh every n-th frame. An application rendering at 30Hz frame rate displaying on a 60Hz monitor updates the image only every second frame, while the video hardware refreshes at 60Hz using the same image for two subsequent frames. A moving line, drawn at 30Hz and displayed on a 60Hz monitor, is reported to result in the perception of two parallel lines moving at the same velocity in spatial neighborhood. Given that the video refresh rate is far above the flicker fusion rate, and that the usual flickering presentation of the line results in stroboscopic motion, the origin of the perceived additional stimulus and its exact position remain unclear.

We conducted a series of experiments investigating potential factors which might affect the perception of those multiple images. First of all, we clearly observed a doubling of the number of perceived lines with half the application frame rate, and a triplication of the number of perceived lines for the application frame rate being one third of the video refresh rate. Varying the video refresh rates between 50 Hz and 150 Hz did not alter the effect. Also, changing the contrast polarity or varying the movement directions did scarcely affect the perception. However, when observers were instructed to fixate a certain point above the monitor or in its center, the number of illusionary lines was greatly reduced. Hence, the results strongly suggest a geometric property generating the illusion: When the eye follows the perceived movement of the line, the first and the second flashes of the line are exposed to differential retinal positions. That is, eye pursuit movements evoke the illusion. The velocity of the line should thus determine the spatial displacement of both perceived images. Similar explanations should also hold for the so-called rainbow-effect in DLP-projectors.

Style Synthesis of Human Body Motion Based on Learned Spatio-Temporal Synergies

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Research in motor control suggests that complex full-body movements might be controlled by the combination of motor synergies, i.e. smaller control units that encompass only limited sets of degrees of freedom [1]. For the generation of perceptually believable complex full-body movements it seems intriguing to devise algorithms that exploit the concept of synergies for the synthesis of body movements in computer animation. Compared to simpler methods for movement synthesis, which typically specify the same motion style for all degrees of freedom, such approaches would permit a more flexible design of animated characters, where e.g. different movement styles can be specified for the upper and the lower body. Such animated stimuli are highly interesting for psychophysical experiments that investigate how the movement styles of different body parts are combined in perception.

We propose a new algorithm for motion morphing that is based on synergies that are derived from motion capture data by unsupervised learning. The learning of synergies is based on the idea that jointly controlled degrees of freedom should show similar timing variations over different action styles. Exploiting a probabilistic framework for dynamic time warping derived from methods in proteomics [3,4], we characterize the time warps between the trajectories of different action styles separately for each degree of freedom. Our algorithm determines synergies by clustering degrees of freedom with similar time warping functions exploiting a probabilistic similarity measure. We also present an extension of a method for the modeling of complex motion styles by linear combination of prototypical trajectories [2]. The new algorithm is suitable for the separate variation of motion styles for individual synergies. This provides higher flexibility for the approximation of novel motion styles based on small amounts of motion capture data, however resulting in very natural animations. In a psychophysical experiment, animation results obtained with the new algorithm are compared with standard methods for motion synthesis. In addition, the proposed method is suitable for investigating how different spatial motion components contribute to the perception of style properties, like emotions.

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Synergy-Based Method for the Self-Organization of Full-Body Movements with High Degree of Realism

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The real-time synthesis of believable human articulated motion is a core problem of computer animation for film and game applications. In addition, such real-time capable avatars offer new possibilities for experiments, e.g. on interactive behaviour or body language. Goal of our work was the development of learning-based methods for the synthesis of highly realistic human movements in real-time. The proposed method is biologically inspired and exploits the concept of synergies, which is derived from motor control. In motor control synergies specify lower-dimensional control units that encompass only a subset of the available degrees of freedom. It has been suggested that complex motor behaviour that is characterized by a large number of redundant degrees of freedom is controlled by a superposition of such synergies [1]. In addition, work in motor control has tried to identify synergies from trajectory and EMG data applying unsupervised learning. We use a similar approach to solve the degrees of freedom problem in full-body animation and developed an algorithm for real-time animation with the following steps: 1) Learning of synergies from sets of motion capture data applying a new algorithm for blind source separation that allows for additional delays of the sources [2]; the individual extracted sources are identified with 'synergies' that form the basis of a generative trajectory model; 2) Approximation of the source signals by solutions of nonlinear attractor dynamical systems, e.g. limit cycle oscillators; the mapping between the attractor solutions and the source signals is learned exploiting kernel methods; the dynamical systems that correspond to different sources are coupled in order to stabilize a coordinated behaviour between different synergies; in this way a real-time capable model for the synthesis of highly realistic movement trajectories of individual avatars is obtained; 3) Introduction of appropriate dynamic couplings between the dynamical systems controlling individual avatars allows the realization of interactive behaviour, like following or obstacle avoidance. The realization of the new algorithm is illustrated for simple applications in computer animation, e.g. the self-organization of coordinated crowd behaviour and the interactive change of emotional styles of autonomous avatars dependent on the behaviour of other avatars or the user. Possible applications of the method in psychological experiments studying interactive behaviour are discussed.

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The Effect of Gaze Direction and Field-Of-View on Speed Constancy

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During linear self-motion at constant speed, the retinal speeds of stationary objects vary as a function of their declination angle (the angle between the line of sight and the horizontal plane). Nevertheless, when we move in our environment, we do not feel that different places move at different speeds: a compensation mechanism is thought to mediate between angular velocity and perceived linear speed so that velocity constancy is achieved. In a recent study [1] it has been shown that the perceived speed is altered when driving with a reduced field-of-view (FOV). The explanation proposed in that study leads us to the hypothesis that, when moving at constant speed, humans might not be able to compensate for the different velocity signals coming from various declination angles when only a limited portion of the visual field is visible. Here we tested this hypothesis using a Virtual Reality (VR) setup that provides a $230^\circ \times 125^\circ$ (H$\times$V) FOV. We measured the visual perceived speed at eye-height (1.7m) while simulating fast walking speeds on a virtual open field. We manipulated the FOV (full field vs. limited field corresponding to an aperture of $40^\circ \times 6^\circ$) and the gaze declination angle (12, 20 and 28 degrees), corresponding to positions on the plane located at a distance of 8, 4.7, and 3.2 m, respectively. We used a two alternative forced choice (2AFC) with constant stimuli method in a 2$\times$3 within subjects design. We tested eight different speeds ranging from 0.67 to 6 m/s. The reference stimulus appeared always in the intermediate declination angle at the speed of 2 m/s. A fixation cross appeared at the desired declination angle 500 ms before each stimulus. At every trial, subjects had to select which of the two presented stimuli indicated a faster linear forward speed. The results of four observers show that when looking with a different declination angle in the test, the perceived speed appeared either higher or lower than the reference speed. This effect was accentuated in the limited FOV condition, suggesting that limiting the FOV impairs the compensation mechanism. Interestingly, while two observers could not fully compensate for the perceived retinal speed even within a full FOV condition, the other two showed a reliable over-compensation independently of the FOV. This indicates that a veridical speed estimation cannot be achieved in VR and with limited FOV and that speed estimation is not independent of gaze direction.

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Perceived Visual Speed while Walking: More than Subtraction

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Perceived visual speed has been reported to be reduced during walking compared to standing still. This so-called 'subtraction effect' has been attributed to an automatic subtraction of part of the walking speed from the visual speed [1]. In this study, we investigated how general this subtraction effect is, by varying visual speed, walking speed and the order of the intervals in which observers walked or stood still. Five observers judged the visual speed of a simulated ground plane that was presented on a HMD in a 2IFC task. In one interval, they judged the visual speed while walking in place on a treadmill (0.6, 1.0, or 1.4 m/s), and they did the same while standing still in the other interval. Simulated visual standard speed, presented during walking, was 1.0, 2.0, or 3.0 m/s. All observers compared the three visual standard speeds during the three walking speeds against a range of visual test speeds during standing still and indicated in which of the two intervals the visual speed appeared to be higher. For three of the observers the order of the intervals was standing—walking, while it was reversed for the other two observers. From the speed judgments, the PSE's in the nine conditions were estimated by fitting psychometric functions. Surprisingly, the PSE's were hardly affected by walking speed. Visual standard speed strongly affected visual speed judgments for the observers who first stood still and then walked. The lowest standard speed was reported to be perceived as slower during walking than during standing still, while the opposite was true for the highest standard speed. When observers first walked and then stood still, this effect did not occur. Taken together, the results question the generality of the subtraction effect and raise doubts regarding the hypothesized functional role of this effect.

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Visual Search for Independently Moving Objects in Complex Motion Patterns

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Problem. Humans easily recognize independently moving objects (IMOs) in static scenes (pop-out effect). However, when the observer is moving more complex motion patterns arise as the IMO motion is superimposed by the self-motion generated optical flow field. Recent psychophysical investigations by Rushton et al. [1] yet revealed a pop-out effect of IMOs also in dynamic scenes. In their experiments only IMOs moving parallel to the translation of the observer (x-condition) were tested. Here, we present an extension of the experiment with IMO movements in perpendicular direction (z-condition). We investigate whether the pop-out effect also emerges in the z-condition, and whether a significant difference for looming or receding IMOs appears. Methods. We use a similar search task paradigm as Rushton et al. (AFC): (1) artificial scenes with multiple objects are generated. While fixating a static point in space, lateral translation of the observer is simulated by displacing the objects in an appropriate manner. (2) After a short delay, one object starts moving independently from all other objects. (3) Subjects (n=6) have to decide as fast as possible in which direction (left/right in x-condition, looming/receding in z-condition) the IMO is moving. We investigate stereo and synoptic presentations as well as different densities (number of objects). Results. For the x-condition our results qualitatively confirm the findings of Rushton et al.: In the stereo case, the reaction times (RTs) for the IMO detection are small and not depending on the object density (pop-out) whereas in the synoptic case RTs are longer and increase linearly with growing density. We observe the same effects for the z-condition, but the RTs are significantly higher than for the x-condition. Concerning the error rates, our results show that in both x- and z-condition significantly more errors appear in the synoptic case. Finally, we establish significantly smaller RTs for the synoptic case for looming compared to receding IMOs. Conclusion. The lower RTs in the stereo case clearly demonstrate that humans can benefit from depth information for IMO detection within complex motion patterns, independently of the IMO direction. This suggests a crowding effect for synoptically presented objects while augmentation with depth might help to segregate on the scene figural objects apart as proposed for cells at the level of area MST. Moreover, the lower RTs for looming in contrast to receding IMOs in the synoptic condition could be induced by a higher sensitivity to approaching objects as they represent a possible threat.

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Visual Perception: Spatial Vision

Relative Mislocalizations of Successively Presented Stimuli

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When observers are asked to localize the peripheral position of a briefly presented stimulus relative to a previously presented comparison stimulus, they tend to judge the probe as being towards the fovea than is its actual position [1]. Three experiments are reported using the method of constant stimuli. Exp. 1 revealed that the mislocalization only emerges when comparison stimulus and probe are presented successively, not when they are presented simultaneously. In addition, the mislocalization increases with decreasing the distance between stimuli (Exp. 2) and the mislocalization is reversed with stimulus onset asynchronies above 400 ms (Exp. 3). The latter two findings point at an interaction of local activation patterns not restricted to the area covered by the stimuli. Rather stimuli spread their activation to and integrate contextual information from the adjacent parts of the visual field.

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Refractive Index and Perceived Transparency

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Almost everything that we think we know about the perception of transparent materials is derived from Metelli's "episcotister model", or some subtle variant thereof. An opaque disk with a missing wedge is rotated at high-speed (above the flicker-fusion threshold), so that its colour mixes linearly with that of the background. And indeed, we have learnt an immense amount about mid-level vision using this model: it applies well to shadows, specularities, stains, black smoke, gauzes, infinitely thin neutral density filters, or any system that generates the linear superposition of two images. However, ironically, it is hopeless as a model of real chunks of transparent stuff, such as ice cubes, quartz crystals, or even a common glass of water. Most real transparent things (i) have non-zero volume, (ii) obey Fresnel's equations (and thus exhibit specular reflection and refraction), and consequently (iii) can elicit the vivid impression of transparency without containing any of the cues traditionally thought to be important (e.g. X-junctions or reduction of contrast in the transparent region).

Here we report the results of several experiments on the perception of refractive index using physically-based computer simulations of light transport through refractive dielectrics. The first experiments use maximum likelihood difference scaling (MLDS) to measure the perceptual scale of refractive index. We find that the scale is positively bowed for all subjects, which means that smaller refractive indices appear more different from one another than larger refractive indices. The shape of the function is not well predicted by simple measures of image-differences.

One of the more obvious potential cues is the pattern of distortions created by refraction of the background through a transparent object. We provide a theoretical analysis of this cue, and derive a measure of the pattern of distortions that the visual system could plausibly perform, called the 'distortion field'. The distortion field, D = div(d), where d is the field of vectors measuring the spatial displacement of features caused by refraction through the object. Although the distortion field varies systematically with refractive index, it is also affected by the object shape, the distance to the background, and the distance to the viewer, so it is an ambiguous cue. In a set of matching experiments, we find that observers make large systematic errors in the estimation of refractive index when these irrelevant scene factors are varied, suggesting that subjects are unable to overcome this ambiguity.

Emphasized Illustrative Visualization for Multiple Objects

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Illustrative rendering techniques have been utilized in the past years to illustrate features and shapes of anatomical objects. Typically, illustrative visualization provides representations that highlight relevant features, while deemphasizing irrelevant details for specific purposes. However, the complexity of the illustration problem increases when rendering multiple neighboring objects. In essence, the relationship between multiple objects still remains difficult to convey. In this work, we present an approach for the combined illustrative visualization of multiple objects. We demonstrate how the appropriate choice of different rendering and shading styles, and the proper parameterization of attributes allow to enhance the perception of the spatial relationship between objects as well as to draw the focus to targeted structures. We classify these objects into focus, near-focus, context, and container objects.

Perception research has shown that certain visual attributes grab one's attention and "pop-out" of a cluttered representation during a visual search [1]. More specifically, in comparison to other attributes, the time it takes to find "pop-out" features in a cluttered field is significantly reduced. Furthermore, it has been shown that the human visual system prioritizes different visual cues; color is prioritized against shape, and brightness over hue (after normalization) [2]. Here, we mainly use saturated hue and silhouettes as preattentive attributes to highlight our focus objects, and to a smaller extent the near-focus and context objects. While silhouettes serve as supportive cues for figure-to-ground segregation [3,4], the thickness of the silhouette reflects the degree of object importance.

Focus objects are emphasized with signal colors that are fully saturated and with full luminance to provide a sufficient contrast to the surrounding objects. Near-focus and context objects are given less saturated, possibly cool colors that are linearly separable to the focus object color to ensure pop-out effects. Significantly less saturated colors with low luminance of a different color category are used for the container objects. Container objects should be shaded with a less attention attracting style (eg. Gouraud shading). On the other hand, near-focus and context objects, cool-to-warm shaded, appear quite clear and distinctive. However, near-focus objects should use a stronger emphasis than context objects. For shading focus objects, halftoning is a good choice, especially for large, innermost objects. Obviously, container objects must be translucent. For all other objects, we apply the degree of interest concept, where objects of the same nesting level from the viewer are given transparencies inversely proportional to their degree of interest.

In summary, we show how the combination of a variety of techniques yields a high quality, expressive depiction of proximate objects in anatomical and technical illustrations.

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