# EWOMS 2005

## European Workshop on Movement Science
## Mechanics
## Physiology
## Psychology

# *Book of Abstracts*

University of Veterinary Medicine Vienna

Movement Science Group

June 2 – 4, 2005

http://www.vu-wien.ac.at/i111/www/EWOMS-2005/

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# Conference Timetable

**Thursday, June 2nd 2005**
| | |
|---|---|
| 10.00 | Reception |
| 11.00 – 13.00 | Buffet Brunch |
| 13.00 – 13.15 | Welcome |
| 13.15 – 14.30 | Plenary Presentation 1 **H. ULBRICH** |
| 14.30 – 15.45 | Mini-Symposium 1 |
| | Mini-Symposium 2 |
| 15.45 – 17.30 | Poster Session Coffee Break, Industrial Presentation |
| 17.30 – 18.45 | Plenary Presentation 2 **A. CLEEREMANS** |
| 19.30 | Welcome Reception/Heuriger/Social Event |

**Friday, June 3rd 2005 - Morning**
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|---|---|
| 08.00 – 09.15 | Plenary Presentation 3 **G.SCHOENER** |
| 09.15 – 10.15 | Mini-Symposium 3 |
| | Mini-Symposium 4 |
| 10.15 – 12.30 | Poster Session, Industrial Presentation |
| 12.30 – 13.30 | Lunch |

**Friday, June 3rd 2005 - Afternoon**
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|---|---|
| 13.30 – 14.45 | Plenary Presentation 4 **M. JEANNEROD** |
| 14.45 – 16.00 | Mini-Symposium 5 |
| | Mini-Symposium 6 |
| 16.00 – 16.30 | Coffee Break, Industrial Presentation |
| 16.30 – 17.30 | Mini-Symposium 7 |
| 17.30 – 18.45 | Plenary Presentation 5 **S. GRILLNER** |

| | |
|---|---|
| 20.00 | Gala-Dinner |

**Saturday, June 4th 2005**
| | |
|---|---|
| 08.30 – 09.45 | Plenary Presentation 6 **C. DE LUCA** |
| 09.45 – 11.00 | Mini-Symposium 8 |
| | Mini-Symposium 9 |
| 11.30 – 12.15 | Coffee Break, Industrial Presentation |
| 12.15 – 13.15 | Mini-Symposium 10 |
| 13.15 – 14.00 | Final Plenary Discussion: Perspectives and Conclusions by a Forum |

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# 1   Plenary Presentations

## 1.1   Movement of walking machines

*Heinz Ulbrich, Sebastian Lohmeier, Thomas Buschmann*
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The movement of walking machines is a complicated process that cannot be controlled by applying strategies known from other technical systems straight-forwardly. Walking can be separated into different phases like single and double limb stance which can in turn be subdivided into smaller phases like loading response, mid stance, terminal stance etc. Similarly to the walking motion the system dynamics can be divided into different parts like upper body dynamics, leg dynamics and the dynamics of the single foot, which play an important role. The performance of walking machines is still far from that of biological systems. Biological control adapts perfectly to environmental changes and requirements while the systems as a whole are self-learning and even self-repairing. One of the reasons for the excellent performance of animals and humans in this area is their excellent sensory perception which still is not fully understood. As mentioned above, the sequence of events during walking cannot be controlled using classical control strategies. This is also due to the lack of sufficiently accurate and fast sensors, which are necessary for applying such strategies to the control of walking machines.  However, biological systems obviously do not use such strategies either, rather relying on redundant sensors, sophisticated sensor fusion methods and other not yet fully understood mechanisms. Technical walking control systems are usually organized in a hierarchical manner with more intelligent, less specialized layers controlling the entire system and more specialized, less intelligent layers controlling individual components. In trying to improve autonomous task planning capabilities, highly developed vision systems play an important role.

Both biological and technological walking require a huge amount of logical decisions which depend on the state of the walking situation and are activated both in normal and disturbed walking.

The presentation will focus on two-, six- and eight-legged walking machines developed at the Institute of Applied Mechanics, Technical University of Munich. The realization of such walking machines including strategies for the mechanical and control system design will be presented, including some short video clips showing the performance of these walking machines.

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## 1.2 Consciousness as global constraint satisfaction: from control to automaticity

Cleeremans A.

Abstract not available at time of printing

## 1.3 Dynamic system thinking: What does it do for understanding movement?

Schoener G.

Abstract not available at time of printing

## 1.4 Simulated actions: an approach to mental kinematics

Jeannerod M.

Abstract not available at time of printing

## 1.5 The intrinsic function of a motor system – from ion channels to networks and behavior

Grillner S.

Abstract not available at time of printing

## 1.6 Control of motor units remains invariant during fatiguing isometric contractions

De Luca C.

Abstract not available at time of printing

# 2   Minisymposia

## 2.1   Behavioral phenomena in sequential behavior

*Convenor: W.B. Verwey*,
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The mini-symposium complements the twin mini-symposium Neural Substrates of Sequential Behavior. Sequential behavior is the organization of typically discrete (may potentially continuous) behavioral elements into temporal sequences that are relevant for the survival of the organism. The resulting behavioral sequences can be of a fixed and stereotyped nature, acquired through repetition, or they may also arise via more on-line mechanisms of composition, based on the assembly of existing sequence elements or subsequences. This mini-symposium will consider research for investigating sequential behavior, especially focusing on the serial RT task.

### 2.1.1   Interactions between stimulus and response sequences in sequence learning

*Michael Ziessler*
University of Sunderland, Division of Psychology

Previous studies in motor control mainly explain the learning and the structuring of movement sequences from properties of the motor system (e.g. Cohen, Ivry & Keele, 1990; Rosenbaum, Kenny & Derr, 1983; Ziessler, Hänel & Sachse, 1990). That means, similarities between the subsequent responses, the frequency of transitions between responses, repetitions of subgroups of responses and others determine the speed of learning and the internal structure. Some studies also considered interactions between the motor system and the perceptive system (Povel & Collard, 1982; Ziessler, 1993). It was shown that the structure of a movement sequence is modified by the structure of the stimulus sequence that triggers the motor sequence. More recent studies on the learning of movement sequences underline the importance of senso-motor interactions for sequence learning. In a variant of the Serial Reaction Task (SRT) we have presented participants different series of stimuli that all resulted in the same response sequence. Interestingly, we found differences in the speed of sequence learning and in the times to execute the response sequences. This is clear evidence against a pure motor based learning of the response sequence. However, the inter-response times did not depend on the stimulus sequence as well. Instead, the relationship between the responses and the stimuli presented following the

responses in the SRT determined the learning of the motor sequence. We interpret this as some kind of response-effect learning. The following stimulus appears as an effect of the response just performed. Based on these results we argue that sequence learning is based on response-effect learning. Response-effect learning seems to be a very fundamental form of learning that also applies under implicit learning conditions.

### 2.1.2 Programming timing during movement sequences: An investigation of Apraxia of Speech.

*D.L.Wrightt[1], C. E. Magnuson[1], D. Robin[2], E. Mass[2], & K. Ballard[3]*
[1]Human Performance Laboratory, Texas A&M University, [2]Speech, Language, & Hearing, San Diego State University, & [3]Department of Speech Pathology & Audiology, University of Iowa.

We have recently investigated motor programming using a two-process model forwarded by Klapp (1995) as a theoretical backdrop. This model proposes two independent processes that (a) involves the initial organization of each unit contained in a sequence (termed INT) and (b) supervises the serial order demand that is apparent when preparing sequential responses (termed SEQ). Previous work has indicated that the cost of INT is impacted by the duration of the individual items within a sequence, while SEQ is related to the number of items that make up a sequence. Recently Immink & Wright (2001) used a modified reaction time (RT) paradigm to simultaneously assess the demands of both INT and SEQ when performing timing sequences. The present work applied Klapp's two-process model of motor programming, using this modified RT paradigm, to assess a recent proposal that apraxia of speech (AOS) involves a disruption in motor programming. AOS is characterized by speech segmentation, evident in increased segment and inter-segment durations, reduced co-articulation, dysprosody, and slow speech. Since AOS rarely presents as a disturbance of serial order (i.e., syllables comprising a word are spoken out of order), we began this investigation with the assumption that the nature of any programming problem would be localized to the INT process in Klapp's model. Moreover, Ballard, Granier, & Robin (2000) have argued that the programming deficit in AOS is not restricted to use of the speech apparatus suggesting that relatively larger programming disruptions such be observed for individuals with AOS even when performing non-speech tasks such as those used in the present work. Six individuals with AOS, six age-matched controls, as well as six younger individuals practiced a non-speech task involving Morse-Code type-responses that entailed single or multiple key presses, each of which had a required duration. A sequence length effect (i.e., RT increased with number of elements in sequence) emerged early in practice and remained throughout which was not unexpected given the moderate amount of practice administered. This finding demonstrated

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a contribution of the SEQ process when producing a sequence with multiple rather than a single key press. Importantly the similarity in the nature of the sequence length effect for individuals with AOS and controls suggests the SEQ process was intact for individuals in AOS. In contrast, two particular findings provide initial evidence for a disrupted INT process in AOS. First, the preparation of a long as opposed to short duration single key press was significantly greater for individuals with AOS which remained throughout practice. While this was true in the initial trials for the control participants, this cost was quickly minimized. Second, AOS displayed significantly greater delays when asked to prepare sequences that involved preparing both long and short duration elements compared to being required to prepare only one duration. Again, such delays were rapidly reduced and disappeared by the end of practice for the age-matched and young controls. The implications of these data for current therapeutic protocols for individuals with AOS will be addressed.

*References*
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Klapp, S.T. (1995). Motor response programming during simple and choice reaction time: The role of practice. Journal of Experimental Psychology: Human Perception and Performance, 21, 1015–1027.

### 2.1.3 Effects of response stimulus intervals and target size in an aiming movement version of the serial RT task

*Inge S. ter Schegget & Willem B. Verwey*
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Implicit learning, the ability to acquire knowledge in the absence of the capacity to verbally express what was learned, has been under investigation for over 35 years. An experimental task that is well-suited to study the acquisition and use of implicit knowledge is the serial reaction time (serial RT) task. This task typically involves successive keypresses, but the present study addressed whether participants develop and use implicit and explicit sequence knowledge also when aiming movements are used instead of key presses. Participants practiced a version of the serial RT task in which they repeatedly cycled through a fixed series of 12 successive aiming movements. Each movement involved tapping a target on a touch sensitive screen. There were six alternative targets located on the perimeter of an imaginary circle and the response to stimulus interval (RSI) amounted to 200 ms. Half the participants tapped 9 mm targets and the other half tapped 24 mm targets. A subsequent test phase examined performance with

the familiar and a random sequence; with blocked RSIs of 0, 200 and 400 ms. The results demonstrate that in the serial RT task implicit and explicit sequence knowledge develop and are used when aiming movement are used. However, even though movement time was longer with small targets, these longer movement times did not affect the development and expression of implicit and explicit knowledge. Detailed analyses suggest that implicit knowledge had its effect during the preceding movement, whereas explicit knowledge was used primarily after the preceding movement had been completed. In conclusion, in the present study target size appeared to determine the time required for hitting targets but this did not affect the development and expression of implicit and explicit knowledge. Explicit knowledge can be expressed better as RSI increases, indicating that explicit knowledge is used primarily after the preceding movement has been completed, while the absence of an RSI effect on the expression of implicit knowledge suggests that implicit knowledge has its effect during the preceding movement.

*Key references*
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## 2.1.4 Anticipatory control of response conflict in a sequence-learning task

*Iring Koch*
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Keywords: Motor sequencing, implicit learning, S-R compatibility, response conflict
Acquired motor sequences, such as in Piano playing, can be performed on the basis of memory. However, learning such sequences usually requires strong stimulus support. The present study investigated the process of learning motor sequences using a serial reaction time (RT) task, in which subjects respond manually to visual stimuli. Sequence-specific learning in such a task is indicated by shorter RTs in predictable relative to unpredictable sequences. It was as-

sumed that sequence learning is at least partly due to a process of motor "chunking," in which subjects learn to anticipate the upcoming response based on the preceding responses. Based on this assumption, it was hypothesized that the learning process should reduce the dependence on the stimulus information when performing predictable motor sequences. To test this hypothesis, two experiments were conducted that examined the influence of sequence learning on the size of stimulus-based response conflict. Experiment 1 compared the performance of two groups that differed in stimulus-response compatibility (SRC), as manipulated by the congruence of the mapping between the visuospatial stimuli and the response keys. Spatial stimuli are assumed to activate spatially congruent responses, so that an incongruent mapping should produce response conflict. The results showed a learning-based reduction of the SRC effect, indicated as a larger learning-based performance benefit in the group with incongruent mapping relative to the one with congruent mapping. Direct memory measures of sequence learning showed that both groups did not differ in the actual amount of sequence-specific learning. Experiment 2 replicated and extended these findings by using predictable sequences of letters (A-D) as response-relevant stimuli, which, however, were unpredictably presented on four horizontal positions to create response conflict based on irrelevant stimulus information (the "Simon effect"). The results showed a reduced Simon effect (i.e., the RT difference between spatially congruent and incongruent trials) as a function of learning response anticipations. Taken together, the data support the assumption that sequence learning leads to the formation of motor chunks, so that stimulus-related response conflicts become less influential.

### 2.1.5 Interactions of implicit and explicit sequence learning

*Aysha Keisler and Daniel T. Willingham*
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The current research examines interactions of implicit and explicit sequence learning in both learning and performance. Rarely do these two types of learning operate in isolation; rather, some combination of implicit and explicit knowledge produces complex skills. We utilize the implicit and explicit forms of the Serial Reaction Time task (SRT), a four-choice reaction time task, in a series of experiments. In the implicit SRT, there is a sequence to the stimuli of which participants are not aware. In the explicit SRT, there is a sequence to the stimuli and participants are instructed to memorize it. The first two studies investigate implicit learning that is acquired in parallel with explicit learning. We hypothesize that the implicit system learns from behaviors associated with the explicit task and not from particulars of the task. In other words, explicit knowledge drives overt behavior and implicit learning is based on these behav-

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iors. Because behavior drives implicit learning, we predicted that stimuli learned explicitly could be changed or removed without extinguishing implicit learning (Experiment 1). To this end, we administered an explicit SRT task with either spatial or letter stimuli. Then, we administered an implicit SRT with the same or different stimuli. We found that changing the stimuli did not affect performance on the implicit task. Thus, the particulars of the task do not support parallel implicit learning. We also predicted that parallel implicit learning will not occur in the absence behavior (Experiment 2). Participants either responded or did not respond during an explicit SRT task and then were tested on an implicit version. Only participants that responded during training acquired implicit learning; thus, behaviors are necessary for implicit learning to occur.

Finally, we examined implicit-explicit interactions in performance. In this experiment, participants trained on both an implicit and explicit version of the SRT. In the test phase, we manipulate task characteristics to determine whether, and under what circumstances, explicit or implicit learning will dominate during performance.

We discuss the implications of these findings to our understanding of memory systems and interactions between memory systems.

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## 2.2   Motor Imagery: neural Mechanisms and clinical implications

*Convenor: Theo Mulder*
University of Groningen, the Netherlands

Motor Imagery is an intriguing phenomenon. During motor imagery more or less the same areas in the brain are activated as during the actual performance of a movement. A number of studies indicated that the repeated imagination of a movement results in a better performance of that movement. Some papers appeared in which it was argued that motor imagery may even be a novel tool for neurological rehabilitation. However, until now, almost no clinical studies took place in which this argument was tested. In spite of this optimism much remains unclear about the neural mechanism that may explain the observed learning effects as a result of motor imagery.

This mini-symposium is focused on motor imagery as one of the main challenges of cognitive neurosciences. It is questioned to what extent motor imagery as a cognitive "skill" is influenced by age or to what extent the obtained learning effects may be explained by a subtle activation of muscles or the activation of the autonomous nervous system. Some insight is given into the potential clinical value of motor imagery.

### 2.2.1 Motor Imagery: a totally central mechanism?

*Th. Mulder, S. Zijlstra, S. de Vries & H. v.d. Worp*
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Motor imagery is a cognitive process in which motor acts are mentally rehearsed without any overt body movements. A fast growing number of studies show that brain areas engaged in the actual performance of movements are for a large part also active during motor imagery. Furthermore, it has been shown that motor imagery may lead to improvement in motor performance. One of the intriguing questions is to what extent peripheral mechanisms such as heart rate, EMG, blood pressure and respiration are influenced by motor imagery. Indeed, if the motor cortex is active during motor imagery, it seems plausible that this activity influences also the motoneuron level and parts of the vegetative system. The results of experimental studies, however, are not unambiguous. Some results suggest that vegetative responses such as heart rate and blood pressure, associated with physical effort vary in the same manner during both motor imagery and motor execution, while other authors were not able to show any activation of peripheral systems in parallel with motor imagery. The present paper is focused on discussing this question. Experimental data of two recent studies will be shown that seem to justify a central explanation of motor imagery without any relevant involvement of peripheral systems.

### 2.2.2 Movement imagery further explored: the effect of age, movement experience and neuropsychological factors on imagery capacity

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The imagination of motor actions forms not only a theoretical challenge for cognitive neuroscience but may also be seen as a novel therapeutic tool in health care, in that it can be used for the rehabilitation of motor disorders due to damage of the central and/or peripheral nervous system. However, since the majority of rehabilitation patients consist of older subjects it is extremely relevant to

know whether the capacity of mental imaging is compromised by age. Scores on the Vividness of Movement Imagery Questionnaire were obtained for 333 subjects, divided in three age groups. Results show that elderly subjects were worse in imagery capacity then younger subjects.

In the presentation we will explore possible explanations for the difference between good and poor imagers in the group of elderly. Data will be presented that show a lessened performance on various neuropsychological tests, but also on a number of movement related variables.

### 2.2.3 Effects of motor imagery training on hand function in chronic stroke patients

*H.C. Dijkerman[1], M. Ietswaart[2], M. Johnston[2] and R.S. MacWalter[3]*
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One of the most common consequences of stroke is a limitation in motor function. Evidence that a) mental tasks can improve stroke outcomes and b) that athletes' performance is enhanced by imagery, suggest that motor imagery techniques may be a valuable in maximizing motor recovery. The aim of the current study was to assess the efficacy of motor imagery training for arm function in chronic stroke patients. The relation between mental processes such as attentional and perceived personal control over recovery, and motor imagery was additionally investigated. Twenty patients with long-term motor impairments (mean two years post stroke), were assessed before and after four weeks of training. Ten patients mentally rehearsed movements with their affected arm. Their recovery was compared with patients who performed non-motor imagery (n=5), or who were not engaged in mental rehearsal (n=5). Assessment and training were performed at the patients' home. The motor imagery group was asked to practice daily imagining moving tokens with their affected arm. The non-motor imagery group rehearsed visual imagery of previously seen pictures. All patients practiced physically moving the tokens. The following variables were assessed before and after training: motor function (training task, pegboard and dynamometer), perceived locus of control, attention control and ADL independence. Each patient group improved on all motor tasks except the dynamometer. Improvement was greater for the motor imagery group on the training task only (average of 14% vs. 6%). No effect of motor imagery training was found on perceived or attentional control. To conclude, motor imagery training without supervision at home may improve performance on the trained task only. The relation between movement imagery, attention and perceived personal control over recovery remained unclear.

### 2.2.4 Neural Consequences of Immobilization and the Role of Motor Imagery in Rehabilitation after Flexor Tendon Lesions

*MW Stenekes[1,2,3], JHB Geertzen[2], JPA Nicolai[3], Th Mulder[1]*
Groningen University Medical Center, [1] Center for Human Movement Sciences, [2] Center for Rehabilitation Medicine, [3] Department of Plastic Surgery, University of Groningen, the Netherlands, e-mail: m.w.stenekes@chir.azg.nl

In a recent PET study on patients who were immobilized for 6 weeks after flexor tendon injury, we demonstrated the impact of a relatively short period of immobilization on the functional organization of the brain. This temporary cerebral reorganization goes together with clumsiness of the splinted hand. Presumably the clumsiness can be prevented if the cerebral reorganization during the splinting period doesn't take place. As a result of diminished input and output, representation on the cortex reduces. Earlier mobilization after flexor tendon injuries increases neural input and output, but also increases the risk of tendon ruptures. Motor imagery generates sensory input and can even lead to an improvement of the actual executed movements. In the current study we examine the opportunities of motor imagery during the splinting period to preserve hand function in patients after flexor tendon injury. A prospective, randomized trail was initiated. Patients with flexor tendon injuries without other disorders that challenge their hand function were asked to participate. All subjects were scanned using the Vividness of Movement Imagery Questionnaire (VMIQ). Subjects were randomized for standard treatment (control group), or standard treatment plus a motor imagery protocol (imagery group). Hand function was assessed at fixed postoperative days: Visual Analog Scale of hand function, Michigan Hand outcome Questionnaire (MHQ), Response time test of finger flexion, Total motion in finger joints and strength. Preliminary data will be presented and discussed

### 2.2.5 Imaging imagined hand movements

*F.P. de Lange, R.C.G. Helmich, B. Bloem & I. Toni.*
F.C. Donders Institute for NeuroImaging, University of Nijmegen, the Netherlands, e-mail: f.delange@fcdonders.ru.nl

Several lines of evidence suggest that when subjects are presented with an image of a hand and have to decide whether it is a left or right hand, they solve this task by imagining their own hand moving from its current orientation into the orientation of the image for comparison. Using fMRI in healthy volunteers, we examined which regions were involved in these imagined hand movements. Furthermore, we investigated how the position of one's own hand influences this imagery process, in terms of behavior and neural response. Finally, we compared imagined hand movements of the left and the right hand in patients

with assymetrical Parkinson's disease who had right-lateralized symptoms. In brief, we found that imagined hand movements recruit a left-lateralized parietal and premotor network. Changing the position of one's arm changes the movement to be imagined, and with it behavior and neural activity in parietal and premotor cortex. Finally, Parkinson's patients with right-lateralized symptoms showed a deficit in imagined hand movements of the affected side, but only when the imagined movement involved more than one component (i.e. rotation plus supination of the arm). This impairment was associated with a decrease of activity in parietal cortex.

## 2.3   The influence of pain on locomotion

*Convenor: Theresia Licka*
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### 2.3.1    Variability of Equine Movement – pain-induced regularity, physiological fluctuation, incoordinated chaos of ataxia

*Licka T[a], Strobach A[a], Kotschwar A[a], Mayhew IG[b], Peham C[a]*
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The aim of this project was to illustrate the range of motion pattern variability in horses with orthopaedic pain, in pain free horses and in horses with ataxia. As in many other areas of physiology, we were able to show a pain induced decrease of variability and the increase of variability with incoordination. For the musculoskeletal system, eg joint cartilage, tendons and ligaments, the increased regularity of motion pattern in the presence of orthopaedic pain is detrimental, with the possibility of developing vicious cycle. Forelimb lameness was documented as percentage of asymmetry of vertical head movement. Ataxia was confirmed with evaluation of videos of neurological tests.The influence of orthopaedic pain on the variation of stride length as a kinematic system-parameter was assessed in 21 horses with forelimb lameness, and compared to data of 15 ataxic horses, and 17 normal horses. Data were collected while the horses were trotting on a treadmill during a minimum of 10s, before and after intra-articular or perineural anaesthesia respectively. Stride length was assessed for each motion cycle, and the mean and standard deviation were calculated for each condition.
Significant differences in stride length variability were documented in our study for all three groups. Our results show that in the presence of orthopaedic pain horses keep stride variability low, in the normal horses a fluctuation of movement pattern variability exists, and in ataxic horses this variability is signifi-

cantly increased.

### 2.3.2 Is extracorporeal radial shockwave therapy a modality in pain management in dogs? A controlled force-plate evaluated study.

*Marion C. Mueller DVM\*, Dragan Lorinson DVM, DECVS\*, Monika Skalicky DTP[+] , Barbara A. Bockstahler DVM\**

Movement Science Group Vienna, Project Group Dog, *Department of Companion Animals and [+]Department of natural science, University of Veterinary Medicine, Vienna Austria

The aim of this study was to investigate the effectiveness of the radial extracorporeal shock wave therapy for the treatment of coxarthrosis in dogs by evaluating ground reaction forces coupled with the orthopaedic examination. Fifteen dogs with mild to severe coxarthrosis were treated three times on a weekly basis with ESWT and examined one week, one month and three months after the last treatment. The dogs were subdivided into two groups depending on the clinical severity and treatment site. The results of the orthopaedic examination of all patients showed a significant amelioration of lameness one week after the last ESWT and a significant amelioration of palpation and range of motion from the third time of examination. The evaluation of the GRF showed for all patients as well for the peak maximal force as for the mean vertical force a significant improvement from the examination one week after the last treatment and for the vertical impulse from the examination one month after the last ESWT. For the statistical evaluation we used a t-test and the 95% confidence interval. We also checked the results for correlation and figured out a significant positive correlation between lameness and the mean value of the orthopaedic examination and also with the ground reaction forces. The diagnostic findings of the radiologic examination showed neither a correlation with the orthopaedic findings nor with the GRF. We also checked the results of the subsequent examinations with the time and found a significant negative correlation. In conclusion radial extracorporeal shockwave therapy is an effective alternative treatment with nearly no side effects in dogs with coxarthrosis, even though further studies with more patients and a control group should be performed. Keywords: extracorporeal shock wave therapy, dog, coxarthrosis, ground reaction forces

### 2.3.3 Pains impact on movements in children and adults with arthritis

*Eva Broström, PhD, PT*

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Pains impact on movements in children and adults with arthritis. Pain in the musculoskeletal system sometimes effects daily life and could give gait distur-

bance and effects physical activity. One method to describe gait patterns is three dimensional gait analyses that is a method for documenting disease progression quantitatively. It may offer important information and thus helping physicians and physical therapist to make better treatment decisions. An early use of gait analysis can be used as an instrument to discover and follow developments of potentially destructive gait deviations. Three dimensional gait analyses, including kinematics and kinetics, provide objective information about gait changes, such as joint angles and moments, which are impossible to examine clinically. The kinematics shows the description of joints movement, including joint segment angles, velocities and accelerations. Kinetics describes the mechanisms that cause movement (e.g., ground reaction forces, joint moments, and joint powers). By combining segment motion and forceplate information, moments and powers can be calculated using a process called inverse dynamics. To highlights different patterns of gait disturbance it is important to interpretate the compensation for pain. Some results have shown a correlation between the levels of perceived pain as measured by visual analogue scale (VAS) and walking velocity of children with arthritis indicating that children with pain walked more slowly. Lower limb strength is vital for proper locomotion. It has been shown that the kinematics of the hip, knee and ankle joints is strongly related to walking velocity and that both the shape and magnitude of the external ground reaction forces is also velocity dependent. In addition to joint pain, this reduction in velocity may partially be due to the functional weakness of the plantar- and dorsiflexors. Muscle weakness and reduction in strength have been shown to have a profound effect on the level of physical activity. There is, however, no correlation between physical fitness and the severity of the articular disease. Children and adolescents with arthritis as well as adults with arthritis can improve their aerobic endurance without increased disease activity, increased pain or radiological progression of joint disease, through participation in physical fitness programs. It is vital to encourage children and adults with arthritis to participate in physical activities as much as possible, since there otherwise is a risk that they end up in a vicious circle with deteriorating fitness. Measuring pain is a challenge since pain is a subjective experience. It is important to be able to measure and quantify the effects of pain on the locomotion system in order to assess the physical impairment that is caused by joint- and muscle pain.

**2.3.4**

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Abstract not available at time of printing

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## 2.4 The role of the lumbar cord in human locomotion

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Central Pattern Generators (CPGs) producing locomotor movements have been extensively studied in limbed and nonlimbed animals. These studies provided definite evidence that the spinal cord of lower vertebrates has autonomous capabilities to produce the basic, coordinated pattern of locomotion. In humans, there have been observations and indirect evidence that some elements of the spinal circuitry on which generation of stepping rhythms relies in lower vertebrates also exists. Experiments of Roaf and Sherrington from 1910, who used repetitive electrical stimulation of the feline cervical cord in studies of neurocontrol of locomotion, as well as following experiments demonstrated that sustained, nonpatterned electrical stimulation can initiate locomotion, when applied to posterior roots of the spinal cord. These studies lead us to our work on neurocontrol of locomotion in humans, as soon as epidural stimulation became a clinical method to control neurogenic pain, spasticity and motor disorders. We approached the human spinal pattern generator by applying sustained electrical stimulation of the posterior spinal cord structures in humans with complete separation of the lumbar cord from brain structures by accidental spinal cord injury. The goal of the minisymposium titled "The role of the lumbar cord in human locomotion" is to review evidence for a spinal pattern generator for locomotion in humans activated by nonpatterned electrical stimulation. Aspects of neurophysiology, biophysics and neuromodeling will be addressed. First we present results demonstrating that peripheral, patterned afferent input generated during the first steps of manually controlled treadmill stepping with partial body weight support cannot induce effective, locomotor like motor units activity in complete spinal cord injured (SCI) subjects.

Second we shall describe the effect of sustained epidural stimulation on human lumbar cord circuitries. The motor output generated by the Lumbar Locomotor Pattern Generator which is triggered and maintained by trains of tonic afferent input will be presented. The main emphasize of the third presentation is to introduce computer simulations of the effect of externally applied electrical fields on neuronal structures. Theories of how the complex interneuronal network of the lumbar cord is activated will be discussed. Fourth, after a brief summary of the neurophysiology of the Spinal Pattern Generator for Locomotion in Humans, the interaction between externally controlled codes for initiation of rhythmical and locomotor like activity will be discussed. On the end an outline of the significance of this work for development of restorative procedures for locomotion in SCI people will be presented.

Keywords: spinal cord injury, central pattern generator, human locomotion, spinal cord stimulation, treadmill training, electromyography, computer simulation

### 2.4.1 Lumbar cord responds to peripheral afferent input

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After complete transection of the spinal cord at the last thoracic segment, cats can be trained to walk within a few weeks with their hind limbs over a treadmill belt while the forelimbs rest on a stationary platform [1]. The same approach of treadmill training with partial body weight support (BWST) is applied as a strategy to enhance walking in patients with spinal cord injury (SCI). The passively induced locomotor movements of paralyzed lower limbs during treadmill training activate spinal neuronal circuits via proprio- and exteroceptive afferents. These afferent inputs generate electromyographic (EMG) bursts with temporal synchronization to specific phases of the step cycle [2]. The aim of this presentation was to study the immediate effect of patterned sensory input to the lower spinal cord induced during the first steps of assisted stepping using BWST in complete SCI patients. In particular, we sought to find out whether stepping-like EMG patterns can be generated by lumbar neuronal circuits under such conditions. Motor units activities of tibialis anterior (TA) and soleus (SOL) muscles of eleven clinically complete SCI patients and of four non-disabled were recorded using surface electrodes during manually assisted, load-bearing treadmill stepping. Results can be divided into two patients groups: Group 1 demonstrated no motor output, patients of Group 2 were showing low amplitude motor output and could be categorized into three subgroups with characteristic EMG patterns: Group 2A demonstrated coactivity of TA and SOL during stance phase, Group 2B had solely activity of SOL and Group 2C showed no SOL, but slight TA output. These results demonstrate that different motor output patterns were induced in spite of the same externally controlled manoeuvre of passive load-bearing stepping. We hypothesize that different central states of excitability of the lumbar spinal locomotor networks caused these different motor unit activity responses to the stereotyped afferent input produced by the manually assisted stepping movements. None of the leg muscle EMG patterns generated during

passive stepping showed alteration between agonists and antagonists characterizing functional stepping-like movement. We conclude that afferent input associated with initial manually assisted stepping using BWST cannot establish a pattern generating set-up of lumbar neuronal networks in the absence of a significant amount of central state of excitability.

Keywords: spinal cord injury, locomotion, treadmill training, electromyography

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### 2.4.2 Lumbar cord responds to sustained tonic afferent input

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The human lumbar cord contains spinal centers capable of coordinating movements of the lower limbs [1,2,3]. Axons which originate from receptors and free nerve endings in muscles, tendons, joints, and cutaneous tissues of the lower limbs enter the cord via the posterior roots and cover the posterior aspect of the lumbosacral cord. These afferents project to motoneurons via mono- and oligosynaptic pathways and via spinal networks involved in gating sensory information and in generating the basic locomotor rhythm [4]. An electrode placed in the epidural space over the dorsum of the human lumbar spinal cord can stimulate the posterior roots and give rise to muscle reflex responses. Stimulus-evoked motor effects induced by regular and repetitive lumbar cord stimulation will be described in this work. We analyzed surface-recorded electromyographic (EMG) responses of the quadriceps, hamstrings, tibialis anterior, and triceps surae muscles elicited by epidural stimulation of the posterior lumbar cord at 1–10 V and 2.2–50 Hz. Seventeen subjects with motor complete, chronic spinal cord injury at levels rostral to the lumbar cord were included in the study. Epidural stimulation of the lumbar cord induced different tonic, patterned tonic and rhythmic lower limb EMG activities. The components of the EMG responses were individual stimulus-triggered compound muscle action potentials. Stimulation at 5–15 and 25–50 Hz could elicit EMG activities appropriate to induce lower limb extension or stepping-like movements, respectively, in the supine subject. Thus, repetitive non-patterned input to the lumbar cord at frequencies of

5–50 Hz was converted to a patterned motor output with defined amplitude modulations of lower limb EMG responses. Epidural lumbar cord stimulation elicited afferent volleys via large diameter fibers within the posterior roots. During locomotion, these sensory fibers transmit phasic input to the spinal cord with spatially and temporally complex patterns. Epidural stimulation elicited a sustained, tonic input that was delivered simultaneously to several lumbar and upper sacral cord segments. Thus, the input was unlike physiological sensory information. We propose, that – besides exerting facilitation of motoneurons pools – the tonic input acts as a common drive to lumbar interneuronal networks. The sustained stimulation organizes the interneurons by temporarily combining them into functional units representing different levels of integrated motor behavior. The set-up of the interneuronal networks depends on the frequency of the tonic input.

Keywords: spinal cord injury; locomotion; epidural spinal cord stimulation; electromyography

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### 2.4.3    Neural responses to epidural stimulation: neuromodeling and the human spinal cord motor control

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Bipolar electrodes placed in the dorso-medial epidural space at lower (lumbosacral) spinal cord levels stimulate sensory fibers of the human spinal rootlets when amplitudes of 210 µs pulses are restricted to 10 Volt. For bypassing axons spike initiation occurs close to the cathode. Sensory fibers below the cathode

level are stimulated at their spinal cord entry point. Dorsal column axons and other neural elements within the spinal cord do not contribute to muscle activation even when they are closer to the electrodes than the excited afferent axons. In subjects with chronic, complete spinal cord injury single pulses and low frequency stimulation cause synchronized short latency muscle twitches via monosynaptic pathways. However, 5-50 Hz stimulation activates spinal interneurons via synaptic connections. These interneuronal circuitries control the motoneuronal discharge and the transmission through reflex pathways and can generate sustained tonic activity and lower limb extension when stimulated at 5-15 Hz and stepping like lower limb movements at 25-50 Hz.
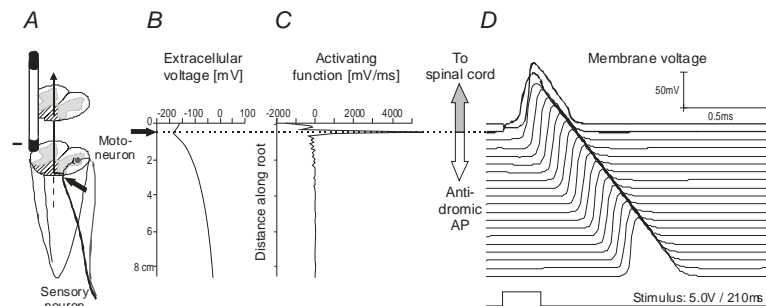
(A) 3-dimensional view of the lower spinal cord with a sensory fiber (within the posterior root, curved trajectory) and its axonal branches in the back side of the spinal cord (hatched area, vertical arrow) with a single synaptic connection to a motoneuron. Black arrows and the dotted line indicate the "hot spot" for the spike-initiation at the site where the posterior root fiber enters the spinal cord. (B) Extracellular voltage generated by epidural stimulation, (C) activating function and, (D) membrane voltage for an S1-posterior root fiber stimulated 4% above the fiber threshold with a midsagittal electrode at L4-spinal cord level. The positive part of the activating function is restricted to a single node (peak). In this hot spot an action potential is generated that propagates into the spinal cord and in antidromic

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### 2.4.4    The human lumbar locomotor pattern generator

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Accidental spinal cord injury (SCI) can divide the lumbosacral cord from brain motor commands. These brain command signals initiate and supervise the activity of the lumbar cord interneuronal network – the Lumbar Locomotor Pattern Generator (LLPG) – involved in controlling standing and walking. The consequence of such complete SCI is the loss of any kind of volitional, postural, or locomotor movements below the lesion level. In addition, when SCI is incomplete, the content of the descending brain command codes to the lumbar cord will be altered. Therefore, the interpretation of the signals by lumbar cord networks for lower limb extension and locomotion will be modified. This results in poorly controlled movements of partially paralyzed lower limbs.We examined the locomotor capability of the lumbosacral cord in individuals with complete SCI by means of epidural spinal cord stimulation. Epidural stimulation was carried out with electrodes placed in the posterior epidural space at vertebral levels T11 through L1. Spinal cord motor output was recorded with surface electrodes placed over the thigh and leg muscle groups quadriceps, hamstrings, tibial anterior, and triceps surae. A variety of non-patterned and patterned EMG activity and movements of the paralyzed lower limbs could be elicited by continuos spinal cord stimulation of the same site of the lumbar cord but at different frequencies [1]. Stimulation at 25-50 Hz elicited a rhythmic EMG activity and initiated stepping like movements of the lower limbs [2]. Stimulation of the same cord structures at 5-15 Hz elicited a tonic EMG activity with characteristic temporal patterns of EMG-amplitude relations between antagonistic muscles appropriate to induce and maintain lower limb extension [3]. The purpose of this lecture is to discuss the neurophysiology and the neural codes for initiation and maintenance of standing and walking, which we learned through our studies in complete SCI individuals. In this human model of the LLPG isolated from brain control, we sought to substitute the missing brain-originated motor command codes by electrical spinal cord stimulation.

Keyword: human spinal cord injury, locomotion, epidural spinal cord stimulation.

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## 2.5   Perception and action dynamics

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The role played by a coalition of constraints of different nature on modulating coordinative stability has recently enjoyed an extensive treatment in the literature on perception and action dynamics. However, a lot of questions remain especially regarding the cooperative/competitive interaction between these constraints on the execution of various coordination tasks. Can goal codes overcome neuromuscular constraints? Is instability of asymmetric movements a product of the complexity of the representation of the event structure of the task? What are the relations between visual search and relative phase perception? Can vision alone sustain spontaneous coordination between two individuals? What is the role played by symmetry and stability on learning dynamics? All these questions were investigated by the speakers of this symposium who join forces in an attempt to shed new light on the perception and action dynamics underlying the execution and the learning of coordinated behavior. Matthias Weigelt will explain how bimanual choice reaction tasks are constrained by the creation and maintenance of goal codes rather than by the properties inherent to the neuromuscular system that carries out these responses. Rebecca Spencer will discuss how instability of asymmetric movements (compared  to symmetric ones) is a product of the complexity of the representation of the event structure of the task. Olivier Oullier will show that unintended synchronization can emerge when two people move in front of each other and only exchange visual information. Raoul Huys will present two experiments in which the relationship between visual search and relative phase perception was investigated. Finally, Pier-Giorgio Zanone will detail his view of learning dynamics especially on the crucial role played by stability and symmetry.

### 2.5.1 Goal-congruency in bimanual object manipulation

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The dexterity of our two hands is strongly affected by a coalition of constraints - whether perceptual, cognitive, neural and/or neuromuscular – enslaving the coordinative system (Carson & Kelso, 2004). Much research has been devoted to investigate constraints at the neural and neuromuscular level (e.g. Carson & Riek, 2000). Recently, however, constraints at the perceptual and cognitive level have gained considerable attraction, where the influence of perceptual effects and action goals on movement coordination has been the focus of research (Mechsner, 2004). In 3 reaction-time experiments, we investigated the impact of action goals on the production of discrete bimanual responses. Similar to a bartender putting 2 glasses simultaneously on a shelf, participants placed 2 objects into either parallel or opposite orientations by carrying out either mirror-symmetrical or mirror-asymmetrical movements. In Experiment 1, performance was strongly affected by the congruency of the intended object orientations but was essentially unaffected by movement symmetry. Experiment 2 replicated this instrumental goal-congruency effect (and the absence of motor-symmetry effects) when actions were cued in advance. Experiment 3 revealed substantial motor-symmetry effects, provided the movements themselves became the action goal. We conclude that performance in bimanual choice reaction tasks is constrained by the creation and maintenance of goal codes rather than by properties inherent in the neuromuscular system that carries out these responses. These goal codes can relate to either body-intrinsic states or to body-extrinsic states according to the actor's current intentions.

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### 2.5.2    A cognitive representation account of coordination stability

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Constraints underlying bimanual coordination have traditionally been explained at the motor level (e.g., Kelso, 1995; Cattaert et al., 1999). For example, symmetric movements are preferred over asymmetric movements, an effect attributed to greater stability for bimanual movements involving activation of homologous muscles. However, the present experiments indicate that such may arise from cognitive constraints reflecting the manner in which task goals are represented. Participants generated symmetric or asymmetric movements at the wrist. Simultaneously, they were instructed to repeatedly verbalize ❝BA❞; importantly, we did not instruct the participants to verbalize at a particular frequency or in a particular phase relationship with the wrist movements. When producing symmetric movements subjects tended to produce one voice cycle per hand cycle; when producing asymmetric movements, two voice productions were observed per hand cycle. Further evidence suggests that complexity is related to the number of salient events associated with the wrist movements. We propose that the instability of asymmetric movements relative to symmetric movements is a product of the complexity of the representation of the event structure of the tasks (Spencer et al., 2003; Ivry et al., 2004).

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### 2.5.3    Spontaneous interpersonal synchronization

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Various studies on interpersonal coordination report that, while moving in front of each other and looking at each other's movement, two persons are able to

maintain stable interpersonal relative phase patterns over a wide range of movement frequencies and limb postures (Oullier et al., 2003; Schmidt et al, 1990; Temprado et al., 2003). Although these studies hint at the efficacy of visual information in sustaining interpersonal coordination, they do not really address spontaneous entrainment *per se*. Where stable patterns could be observed, the constant presence of instructions to synchronize, a pacing metronome and/or a limb to track preclude definitive conclusion about the emergence of mutual entrainment. However, other studies revealed that mere observation of movement of another person affects motor responses strong enough to interfere with one's execution of a similar action (Kilner et al., 2003; Schmidt & O'Brien, 1997). In the present study, we test the hypothesis that unintended synchronization can emerge spontaneously between two people. Pairs of participants executed rhythmic finger flexion-extension movements, each at their own preferred frequency and amplitude without any external pacing. Subjects sat facing each other grasping horizontal dowels with their right hand in pronate position. Each trial was divided into three contiguous periods during which visual exchange between the participants was controlled by instructing *a priori* each of them to either keep his/her eyes open or closed without interrupting the ongoing movement. Two conditions were tested: (1) both participants with eyes Closed-Open-Closed (*COC*) and (2) both participants with eyes Open-Closed-Open (*OCO*). When their eyes were open participants were required to look at each other's finger movements without any instruction regarding the way (or if) they should synchronize their the oscillations of their fingers. Results show that when they exchanged visual information (both participants with eyes open), the movements of the participants became spontaneously synchronized despite the absence of any explicit instruction to do so. The entrained movements were predominantly in-phase. When visual exchange was removed (both participants with eyes closed), the entrainment was lost. We report that humans involved in oscillatory behavior exhibit spontaneous synchronization phenomenon when communication with neighbors is allowed, even if they are not asked to do so. These results indicate that visual information provides a powerful constraint on the ability of two individuals to produce both independent and coordinated behavior.

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### 2.5.4    Optical relative phase: Visual search and information pick-up

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Recently, distinctive features of relative phase perception have been demonstrated (cf. Zaal *et al*., 2000; Bingham *et al.*, 2001). It has not been established conclusively, which stimuli properties underlie these features. One way to bring light into this issue is by studying the relationship between visual search and relative phase perception. In two separate experiments, we examined visual search patterns while participants made judgements of visually presented relative phase patterns (Experiment 1) and while they performed uni-manual tracking movements at particular phase relations with an oscillating visual stimulus (Experiment 2). Nine participants took part in both experiments. In Experiment 1, the mean and variability of participants' estimations as well as the degree of stimulus-gaze coordination was examined as a function of relative phase (0º, 45º, 90º, 135º and 180º), stimuli visibility (entirely visible, occlusion of inner and outer parts of the stimuli trajectories), and amplitude (5º, 10º and 20º). In line with previous research, the mean of the relative phase estimations was similar to the presented relative phases, whereas the variability resembled an inverted U-curve as a function of relative phase (cf. Zaal *et al*., 2000; Bingham *et al.*, 2001). The visibility and amplitude manipulations hardly affected this pattern. The degree of stimulus-gaze coordination decreased as relative phase increased; in contrast, the variability of this coordination correlated with the variability of the phase estimations. In Experiment 2, the stability of tracking per-

formance as well as the degree of stimulus-gaze coordination was examined as a function of produced relative phase (0º and 180º) and the same visibility and amplitude manipulations as in Experiment 1. Manual tracking performance deteriorated when only the inner part of the stimulus and the feedback signal was visible, as amplitude decreased, and in antiphase relative to in-phase tracking. Stimulus-gaze coordination was weaker when the stimulus and feedback signal were partially occluded and as amplitude increased. Stimulus-gaze coordination was stronger during in-phase than during antiphase tracking. Finally, stimulus-gaze coordination was higher when actively establishing a relative phase relationship compared to looking at visually presented relative phases only. The results suggest that the role of gaze in the perception of relative phase depends on the task context (i.e., perceiving versus producing phase relations) as well as the presented or required phase relation, which may imply that the nature of information pick up, as well as the information used to resolve relative phase, might depend on the prevailing task constraints.

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### 2.5.5    Learning dynamics: Stability, symmetry, attention, and memory

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The process of learning coordination patterns follows two routes, depending on the relationship between the learner's existing repertoire (captured as underlying coordination dynamics that bring about the behavioral patterns performed spontaneously) and the task to be learned (Zanone & Kostrubiec, 2004): a *bifurcation* route, where a coordination pattern is created anew, and a *shift* route, where a pre-existing pattern is biased toward the task requirement. Theoretical work reveals that the learning routes differ profoundly, especially in terms of symmetry, and that the route that maximizes stability as learning proceeds is the one actually selected (Zanone *et al.* submitted). The empirical consequences of such a selection are not trivial: The shift route, due to the lesser stability attained, requires more attention (Jouhet *et al.*, submitted) to sustain the learnt pattern, which is then more prone to be forgotten over time (Tallet *et al.*, in preparation). These findings suggest that the bifurcation route may be more beneficial on the

long run ("true" long-term learning) to comply with the task requirement than the shift route ("mere" short-term adaptation). This dynamic view of learning, based on the central notions of stability and symmetry, provide a blueprint for a general theory of learning and transfer, encompassing two important topics in behavioral sciences, attention and memory, that have long been associated, albeit somewhat loosely, with learning.

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## 2.6  Neural Substrates of Sequential Behavior

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Sequential behavior is the organization of typically discrete (may potentially continuous) behavioral elements into temporal sequences that are relevant for the survival of the organism. The resulting behavioral sequences can be of a fixed and stereotyped nature, acquired through repetition, or they may also arise via more on-line mechanisms of composition, based on the assembly of existing sequence elements or subsequences. This mini-symposium will consider the neurophysiological mechanisms underlying sequential behavior along this continuum. Apicella thus describes distinct task related populations of neurons in the primate striatum during the execution of a serial reaction time task. He will demonstrate that while one population appears to encode the structure of the learned sequence, a second displays activity inversely related to the predictability of reward, thus providing insight into the representation of automated sequential behavior in the striatum. Moving towards a more compositional binding of sequence chunks, Verwey et al. examine human performance in the discrete sequence production task, revealing behavioral evidence for a chunking strategy. Subsequently, low frequency off-line stimulation of the SMA eliminates this effect, suggesting a role of SMA in the execution of sequence fragments or chunks in the context of larger behavioral sequences. In an effort to examine the possible mechanism of this chunking, Sallet et al. report on task related neural activity recorded in the primate anterior cingulate cortex during a task in which a behavioral sequence is interrupted by a subtask that must be completed before the main sequence is resumed. Three populations of cingulate neurons were active before, during or after the interrupting sequence, sug-

gesting decomposition of the hierarchical task into a limited number of behavioral chunks, potentially simplifying the problem. Further investigating the ability to generate behavioral sequences "on the fly" Dominey reports on data from human subjects and neural network simulations in a task in which the choice of a particular chunking structure of behavioral sequences is indicated on-line by a special category of sequence elements. ERP studies reveal a left anterior negativity in response to these "function" elements that is comparable to that observed for grammatical functions words in a related language processing task. The symposium will close with a discussion of how these data from the four studies can be integrated into a "next generation" neurocomputational model of sequential behavior.

### 2.6.1 Neuronal activity in the striatum during performance of automatized sequential movements

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Experimental studies on motor learning have shown that a distributed network of cortical and subcortical areas is associated with the production of sequential activities. The basal ganglia are thought to be involved in the procedural learning that leads to habit formation. Previous studies have shown that neurons in the striatum, the principal constituent of this subcortical system, change their activity flexibly during learning of visuomotor associations and the performance of automatized procedures. To test whether the striatum has a role in the retention of sequential actions, we trained macaque monkeys to perform a serial reaction time task that involves sequential arm reaching movements to spatially distinct targets. Animals were trained with the same serial structure consisting of a repeating series of three target locations. Sequence learning was assessed by comparing performance when stimulus locations follow the repeating sequence, as opposed to a random order. After extensive practice of the same spatial sequence, the monkeys made speeded motor responses with an increased tendency for eye and arm movements to occur in an anticipatory manner, suggesting that the sequential action had become automatic. At this stage of learning, single neuron activities were recorded in the anterior part of the caudate/putamen and the posterior putamen. Neuronal activity was compared in the two task conditions (sequence versus random). Neurons with very low levels of spontaneous activity, which are considered to be striatal projection neurons, exhibit transient or sustained increases in firing rate at various phases of task performance and we focused on neurons showing anticipatory activity preceding the trigger stimulus for movement. Some of these neurons were activated selectively during performance of the accustomed sequence of movements, suggesting that they are related to the retention mechanism of sequential movements. On the other

hand, the activity changes that we observed in tonically active neurons (TANs), presumed to be striatal cholinergic interneurons, contrast with those reported for the projection neurons. They respond in a largely homogeneous fashion to stimuli eliciting movements to obtain reward. However, TANs reduced or lost their responses to task events whose onset time is highly predictable and they usually did not differentiate between repeating sequence and random order of stimulus presentations. These results suggest that sequential actions that are guided by automatized procedures are represented in neural networks involving the striatum.

### 2.6.2    On the role of the SMA in the discrete sequence production task. A TMS study.

*W.B. Verwey, R. Lammens, & J. van Honk*

Participants practiced two discrete 6-key sequences for a total of 420 trials. The 1x6 sequence had a unique order of key presses while the 2x3 sequence involved repetition of a 3-key segment. Both sequences showed a long interkey interval halfway the sequence indicating hierarchical sequence control in that not only the 2x3 but also the 1x6 sequence was executed as two successive motor chunks. Besides, the second part of both sequences was executed faster than the first part. This supports the earlier notion of a motor processor executing the elements of familiar motor chunks and a cognitive processor triggering either these motor chunks or individual sequence elements. Low-frequency, off-line transcranial magnetic stimulation (TMS) of the supplementary motor area (SMA) counteracted normal improvement with practice of key presses at all sequence positions. Together, these results are in line with the notion that with moderate practice, the SMA executes short sequence fragments that are concatenated by other brain structures.

### 2.6.3    Interference control in the Anterior Cingulate cortex

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In human and non-human primates, the prefrontal cortex -including the Anterior Cingulate cortex (ACC)- is known to subserve higher executive functions such as task management and planning. The disorders of temporal integration after prefrontal lesions are accompanied by an inability to avoid interferences from both the external and internal sources. More specifically, the ACC is thought to participate in planning by monitoring conflict and/or reward-oriented behaviors. In the present experiment, we test whether and how the anterior cingulate is engaged in the process of controlling interfering sub-tasks while the subject

holds temporarily in mind an ongoing rewarded task. The animal pressed a se-
ries of 4 fixed (green) targets in a fixed order to get a reward. This series of
target touches (called the main sequence) was  -or was not- unexpectedly inter-
rupted by the onset of 2 out of 6 (red) targets that the animal also had to press in
a fixed order (the interfering sequence). When the interfering sequence was
terminated, the animal had to return to the main sequence and resume the
touches of the targets from where they had been interrupted. The monkey was
then rewarded. We compared neuronal activity in the main and interfering se-
quences.  The neuronal data show that task-related cells belong to 3 different
groups: cells active before, during and after the interruption. The great majority
of the task-related cells were activated during the interruption, i.e. when the
action is diverted from its goal. These data provide evidence that sequences of
acts are decomposed in the ACC into a limited number of behavioral chunks.
The division in chunks may have a role in sequence monitoring. It provides a
framework in which the action can be organized with respect to clearly defined
sub-goals or sub-tasks. It allows to link individual acts to each other, to their
sub-goal, to the general plan and to the final goal. It increases the capacity of the
working memory and allows incorporating new elements or new actions in a
trial while maintaining unchanged the general behavioral structure. The division
in chunks might also correspond to specific needs for control. The hypothesis is
being tested that increased activity also corresponds to increased needs for con-
trol, i.e. to periods of increased rate of errors and increased response times.

### 2.6.4    On-line Structural Processing of Behavioral Sequences and Lan-guage:  A Neurocomputational Model

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Part of the versatility of human and non-human primates derives from their
ability to generate novel behavioral sequences based on the real-time require-
ments of survival.  In order to investigate this behavior we developed a serial
reaction time sequence learning task in which subjects learned an "abstract
structure" rule of the form 123-213 through practice with a sequence such as
ABCBAC.  Knowledge of the abstract rule was demonstrated by the subject's
ability to transfer the knowledge to a new sequence such as DEFEDF that fol-
lowed the target abstract structure.  Simulation and behavioral experiments
suggested that recurrent network for sequence learning could not perform this
task.  The model required an additional capability to store the recent sequence
history, and compare this with new elements in order to recognize and store the
repetition-based abstract structure.  The resulting "dual mechanism" model
reproduced human behavior. In order to allow the system to manipulate multiple
such rules, we introduced the notion of a "function symbol" that explicitly

marked the appropriate transformation or rule directly within the sequence. This yielded abstract structures such as 123X213 and 123Y123 where the function symbol X indicates the "213" transformation, and Y indicates no transformation. At this point we can define a functional analogy between this processing and sentence comprehension. Consider a task in which given a sentence, the response is the ordered set (agent, object, recipient). Thus for "John gave Mary the Ball" the response is (John, Ball, Mary). Likewise for "The Ball was given to Mary by John" the response is (John, Ball, Mary). Now, this task can be recharacterized in the context of abstract sequence processing as "JMB-X-JBM" and "BMJ-Y-JBM", where X and Y play the functional role of the grammatical function words "to" and "by" in the sentences. In this context we demonstrated that the same model could perform the abstract sequence processing tasks, and a well documented task of syntactic comprehension. By definition, the model embodies the hypothesis that the same neurocomputational mechanisms are at work for sentence and sequence processing of this type. Results from ERP and fMRI studies will be presented that support this hypothesis and demonstrate how rules for sequencing can be triggered on the fly by structural cues embedded within the sequence.

## 2.7 Dynamical approach to timing and sensorimotor coordination

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Over the past twenty years, a considerable interest has been devoted to the dynamical analysis of timing and sensorimotor coordination. The basic idea of research programs elaborated in this perspective is that timing and coordination must be studied through their changes of states in the course of time. These changes are often cast in a mathematical form which provide guidelines on how to model their dynamics The proposed symposium presents various paradigms in the study of the dynamics of timing and sensorimotor coordination. The two first presentations deal with dynamical analysis of time series of summarizing oscillatory behaviors. Lemoine, Torre and Delignières present an application of spectral analysis to time series interval produced in synchronization-continuation tasks, either with finger tapping or oscillating a hand. They use the typical observed spectrum for the oscillatory condition to infer what kind of timer is specifically exploited. Teulier and Delignères address the issue of con-

tinuity and discontinuities in learning a rhythmic task involving oscillations of the whole body (i.e., a swinging task). They analyze the evolution of oscillatory behavior during the course of learning and show that before exploiting a single stable "expert" swinging strategy, participants exhibit periods during which the expert-like behavior alternated with a less efficient one. The three following presentations deal with the dynamic pattern approach to coordination. Sallagoity and collaborators present experiments aiming to establish which coordination dynamics underlie handwriting. Using a paradigm inspired by Kelso's (1984) experiments on bimanual coordination, they show that graphic skills exhibit preferred patterns, nonlinear transition, and predictable deterioration based on the relative stability. Salesse and Temprado are interested in the coalition of muscular and spatial constraints that govern interlimb coordination. They show that these constraints may play either a dominant or a subordinate role as a function of task-context. Milliex, Calvin and Temprado address the issue of the coalition of constraints in perception-action patterns. In particular, they assess the (neuromuscular and informational) origins of the recruitment of a new degree of freedom in adduction-abduction movements of index finger. They show that the recruitment of the vertical plane of motion contributes to the stability of perception-action patterns and that any changes in stability of coordination patterns also influence the recruitment of the vertical plane of motion. Overall, among others, these works promote the theoretical framework of dynamical systems analysis to the status of valuable resource for building research programs in Human Movement Science.

Key-word: Dynamic pattern theory, Nonlinear coupled oscillators, timing, coordination.

### 2.7.1    Spectral analysis of time intervals production: From cognitive to dynamical timers

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Timing has been for a long time conceived as a unitary mechanism. The most popular model was proposed by Wing and Kristofferson (1973), suggesting that time control is based on the production, by an internal clock, of a series of discrete events triggering the execution of behavioral responses. Robertson et al. (1999), nevertheless, evidenced that temporal precision in tapping is not related to temporal precision in continuous drawing. Zelaznik et al. (2002) showed that tapping or intermittent circle drawing is governed by an explicit timing process based on explicit temporal representations.

Conversely, timing in continuous circle is sometimes considered as an emergent property. For instance, Spencer et al. (2003) showed that cerebellar patients had

specific deficits on discrete rhythmic tasks, but not on continuous tasks. Schöner (2002) proposed to distinguish two kinds of timers: event-based timers -- controlling rhythmic motion by the production of discrete cognitive events -- and dynamic timers based on the assumption that the dynamics of oscillatory effectors could act as time controller. Gilden et al. (1995) performed spectral analyses of time intervals series produced in tapping. They showed that the internal clock exhibited a 1/$f$ behavior, suggesting that cognitive process but rather should be considered as the superposition of multiple components running at different frequencies and resulting in a complex dynamical behavior. Secondly, they showed a typical signature for event-based timers: plotted in log-log coordinates, the power spectrum exhibits a positive linear trend at high frequencies, indicating the presence of a differenced white noise process within the series. Such process was postulated in the Wing and Kristofferson's model. According to Schöner (2002)'s assumptions, one could suppose that time intervals series produced dynamically should not contain such differenced white noise process. Delignières, Lemoine, and Torre (2004) tested this hypothesis by comparing the log-log spectra obtained from time interval series produced in tapping or by the continuous oscillation of the forearm. Their results replicated those of Gilden et al. (1995) for tapping, and evidenced a typical spectrum, contaminated by a single white noise process, for the oscillatory condition. These contrasted spectra constitute the respective typical signatures of event-based and dynamical timers, and could be used as suitable indices for detecting what kind of timer is exploited in a given task or condition. Our current research aims at thoroughly studying these two kinds of timing processes, and especially at understanding the 1/$f$ behavior, which appeared common to both timers.

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### 2.7.2    Dynamics of recruitment-suppression of degrees of freedom in perception-action tasks

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Motor coordination may be understood using the dynamic pattern theory (DPT). In this framework, coordination dynamics (preferred patterns, (in)stability and

phase transitions) have been extensively studied in bimanual task in which the displacement of the fingers was restricted to the horizontal plane of motion. However, in tasks involving abduction-adduction movements of the fingers, it has been shown that the system can spontaneously recruit the vertical plane of motion [1]. In the DPT, the recruitment of quiescent degrees of freedom (dfs) is considered as a spatial transition. The goal of our research program is to explore the relationship between the coordination stability on the horizontal plane and the recruitment of the vertical plane of motion. We studied perception-action tasks requiring the coordination between abduction-adduction index movements and an auditory metronome. We measured the relative phase and its variability, number of transitions and the magnitude of recruitment of the vertical dimension. In a first experiment, we modified the stability on the horizontal plane by providing a haptic contact either in coincidence or counterphase with the metronome [2]. Results showed that any change of pattern stability in the horizontal dimension led to a change of recruitment. Moreover, the abduction-on-the-beat pattern was intrinsically more stable and involved recruitment of larger magnitude than did the less stable adduction-on-the-beat pattern. We concluded that the larger recruitment observed for the abduction-on-the-beat pattern contributed to improve pattern stability. A second study confirmed this hypothesis [3]. In this experiment, index finger movements were either free to move or physically constrained to the horizontal plane. The more stable abduction-on-the-beat pattern which recruited the vertical plane in the free condition was destabilized when the recruitment was prevented. Results suggested that the recruitment of the vertical plane increased the stability of the abduction-on-the-beat pattern. In a third experiment, we compared two coordination modes differing in their stability (i.e. synchronization and syncopation) and we analyzed their effect on the recruitment. Results showed that, for both the abduction and the adduction pattern, the synchronized mode was more stable than the syncopated mode. However, the recruitment of the vertical plane of motion was not affected by coordination modes. On the other hand, for both coordination modes, abduction patterns were more stable and recruited more than adduction patterns. Taken together, these results show that recruitment of dfs is related to pattern stability and may be functional to maintain the required coordination pattern. However, they strongly suggest that the occurrence of recruitment predominantly depends on the (in)stability caused by the neuromuscular constraints. Keywords: Coordination dynamics, Self-organization, Recruitment of degrees of freedom, perception-action pattern.

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### 2.7.3 Inter-Limb Coordination Dynamics as a Result of a Coalition of Constraints

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During the last twenty years, most studies have been interested in determining how multiple constraints ranging from 'high-level' cognitive-perceptual to 'low-level' neuro-muscular may influence spontaneous interlimb coordination dynamics. Though it is widely accepted that coordination dynamics is the result of a coalition of constraints, the interactive effects between the different constraints has been sparsely studied. In this symposium, we will present three experiments carried out to investigate the interplay of muscular (the relative timing of activation of homologous muscles), directional (the relative direction of the limbs refered to a common space), and planar (the plane of motion in which the tasks are performed) constraints on both stability and accuracy of preferred rhythmic interlimb coordination patterns. In these studies, we used different coordination tasks (hand-foot, bimanual) under different paradigms (vision, no vision, transformed feedback) to investigate the nature of the interaction between the different constraints. In a first study, we investigated the interaction of neuromuscular and directional constraints in hand-foot coordination (Salesse, Temprado & Swinnen, 2005). Results showed that, relative direction of moving limbs predominantly influences the stability of coordination patterns independently of the type coordination performed and that muscular constraints only played a subordinate role. Moreover, results also showed that directional constraints have a visual basis. In a second study, we adressed the issue of whether isodirectionality principle observed in interlimb coordination performed in the sagittal plane of motion is, at least partially, visual in nature (Salesse & Temprado, 2005). Results suggest that the role of visual information (visual grouping principles) seems to depend on the congruency between visual (as an (in)congruent movement consequence) and proprioceptive feedback (Salesse & Temprado, 2005; Salesse et al., 2005). Finally, in a third experiment, we assessed the role of the plane of motion in which (bimanual) movements are performed on pattern stability and accuracy (Salesse, Oullier, & Temprado, under revision). Results showed that the plane of

motion in which tasks are performed influences the stability of rhythmic interlimb coordination and seems to act as a control parameter on bimanual coordination dynamics. In the end, an experimental strategy to further explore this hypothesis will be presented.

Keywords: Self-organization, egocentric constraint; allocentric constraint; visual perception

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### 2.7.4 Nonlinear coupled oscillators dynamics govern the production and degradation of handwriting

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Handwriting requires an exquisitely tuned coordination to produce legible words. Nevertheless, this legibility can be altered by various constraints, such as speed or stress, which may have deleterious scholar, professional, and social consequences. Handwriting is considered as a sequence of cyclic movement and results from the coordination of two orthogonal coupled oscillators (Hollerbach, 1981). We bear on the assumption that handwriting results from the dynamics of non-linear coupled oscillators. Our main concern was to draw dynamical phenomena that govern the formation of graphic patterns, their co-articulation, and their destabilization under various constraints. We present here three experiments aiming to establish which coordination dynamics underlie handwriting. The basic idea is to have right-handers produce 13 shapes corresponding to fixed values of relative phase between the two orthogonal oscillators. Athènes *et al* (2004) revealed that only four patterns were spontaneously stable (0°, 45°, 135° and 180°), corresponding to ellipses (45° and 135°) and strokes (0° and 180°) in various orientations, and characterized by attraction of nearby shapes and differential stability. In accordance with such differential stability, Sallagoïty *et al.* (2004) confirmed that under a high movement velocity or with the non-dominant hand, the least stable pattern degraded most, whereas more stable

patterns remained more accurate and stable. Our last study explored the rules of transition between all pairs of the four preferred coordination patterns of handwriting. Seven right-handers were instructed to produce two patterns which appeared successively in a digital tablet and to perform the second pattern as soon as it appeared without lifting the pen. Each transition has been produced from the most to the least stable pattern, and vice-versa. Results showed that for all transitions, the time to switch from a more stable pattern to a less stable pattern was longer than the other way round. Moreover, such a switching time increased when participants had to change the spatial orientation of the produced pattern during the transition. Then, the rules of transition between graphic shapes depend on their relative stability as well as their spatial orientation. Alike all periodic motion, graphic skills exhibit preferred patterns, nonlinear transition, and predictable deterioration based on the relative stability. This corroborates that handwriting are governed by the dynamics of non-linear coupled oscillators. This opens a new window into understanding the production of handwriting and drawing robust predictions about its acquisition and degradation.

Key-Word: Intentional switching, Attractors, Dynamic pattern theory, Nonlinear coupled oscillators, Graphonomics.

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## 2.7.5     The transition between novice and expert behavior during learning

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Motor learning is currently conceived as a discontinuous process, but the question of the nature of discontinuity is a matter of debate. Zanone and Kelso (1992) on the basis of their experiments on bimanual coordination, considered learning as a phase transition between two stable states (e.g., characterizing initial and expert behavior). This conception is consistent with several experiments showing qualitative differences between beginner and expert behaviors: Temprado et al.'s study (1997) on volley-ball service or Delignières et al.'s work (1998) on complex gymnastics skill. In these studies, a continuity between the two coordinated behaviors seemed unlikely, supporting the idea of qualitative change between two successive modes of coordination.However, these experiments did not analyze the transition from one coordination mode to the

other during the course of learning. Nourrit et al. (2003) developed a new method for assessing dynamical properties of learners' behavior. Using a modified mono-ski simulator, they analyzed the evolution of damping of oscillatory movements of the body during the course of learning. Results showed that from the very first trials, all participants displayed a Rayleigh-like damping behavior. Later in course of learning, transition occurred for all participants to a van der Pol-like behavior. This transition was not abrupt, but was characterized by a quite long bi-stable transition period. This kind of transition could represent a special case of saddle-node bifurcation, with a non-linear evolution of control parameter. It could also be conceived as a parametric evolution of a hybrid model, combining Rayleigh and van der Pol terms.

To differentiate these two hypotheses we carried out an experiment in which 1) no solution of continuity could be possible between beginner and expert behaviors and 2) a sufficient practice time was allowed to induce stabilization of the new coordination pattern. We have tested the evolution of coordination modes in a swinging task. Our results showed that, at the end of the learning, participant exploited a forcing strategy characterized by two symmetrical forcing actions per cycle (located at the reversal points of the swing). The adoption of this behavior was preceded by a stage during which this expert behavior was exploited in alternation with a more basic behavior, characterized by a single forcing action per cycle. This results suggest that transition between novice and expert behavior is realized trough a transient stage during witch these two coordination modes are exploited in alternation.

Key words: Dynamical system approach, learning, gross motor skills.

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## 2.8 Muscles and modelling and analysis of human gait

*Convenor: Martin Sust*

### 2.8.1 General requirements on forces laws

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Since 1687 movements in inertial systems can be described by Newtons axiom $F=d(mv)/dt$ or by the equations $D = d(J \omega)/dt$ derived from these relations (F and D force and torque vector, resp., v and $\omega$ velocity and angular velocity, resp., m mass and J inertia tensor and t time). These relations are always fulfilled for human movements. They can be applied for arbitrary complicated models. If we know the quantities on the right hand side of the above equations (e. g., by measurements) and calculate the left hand side, this is called „direct dynamic", the other direction is called „inverse dynamic". For both cases there are lots of results. However, it is in principle not possible to predict a movement, because it is not known which force the force producing systems will develop under certain conditions. This situation changes immediately if we know so-called „force laws", e.g., $F = \gamma m_1 m_2 r^{-3} r$ for the gravitation ($\gamma$ denoting a constant, $m_1$ and $m_2$ masses, and r distance vector with length r), or $F = - k \Delta x$ for the linear spring (k spring constant and $\Delta x$ change of length). For human movements it is essential to know (Sust, 1978) if and under what circumstances there is also a force law for the muscle force. Following the proof of Bernstein (1967, originally 1935) Sust 1989 showed that in the general case a force law for muscles cannot have a simpler structure than $F=F(l,v,A(l,v,t))$. Here l denotes the muscle length, v the contraction velocity, and A the activation of the muscle. Force laws of this structur have not (yet) been found until now. Hill's relation of 1938 $(L+a)(v+b)=c$ (L moved load, v contraction velocity, and a,b,c muscle specific constants) can only be a special case or an approximation for special conditions. This is the background for misunderstandings and false interpretations of Hill's equation. For the application of Hill's equation as a force law it is necessary to clearify this. Do do this, Hill type experiments are newly interpreted within the measurement accuracy, approximations are found by suitable Taylor expansions, and functions of activation are introduced.

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### 2.8.2     How to measure muscle properties?

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In general, muscle models are used to simulate the movement of humans and animals. On the other hand muscle models help to understand the mechanical properties and behavior of muscles. Models require physiological muscle properties as input parameters. Presently it is impossible to determine a complete set of individual human and animal muscle properties *in vivo*. Therefore it is generally accepted to estimate muscle properties by physiological cross sectional area, fiber type, and other external parameters. To improve model predictions it is necessary to determine muscle properties individually. Force production by an active muscle depends mainly on the force-length relation, the force-velocity relation, and the series elasticity. Typically a number of experimental methods must be used to measure these muscle-tendon properties, including isometric, isotonic, isokinetic, and quick-release experiments. In general these methods are complicated and time consuming. A large number of muscle contractions are necessary to complete all the required measurements, and for some muscles fatigue may preclude accurately measuring all properties on a single preparation. This study validates a simpler method (ISOFIT) to determine muscle properties by fitting a Hill-type muscle model to a set of isovelocity data. Muscle properties resulting from the ISOFIT method agreed well with muscle properties determined separately in *in vitro* measurements using frog semitendinosus muscles. The force-length curve was described well by the results of the model. The force-velocity curve resulting from the model coincided with the experimentally determined curve above approx. 20 % of maximum isometric force ($R>0.99$). At lower forces and thus higher velocities the predicted curve underestimated velocity. The stiffness of the series elastic component determined with direct experiments was approx. 10 % lower than that determined by the ISOFIT method. Using this set of muscle properties it is possible to simulate, e.g. realistic movement of antagonistic human leg and arm muscles (Sust et al. 1997; Wagner and Blickhan 2003), reactions of muscles following perturbations (Siebert et al. 2003a) and work loop simulations (Siebert et al. 2003b). Determination of muscle properties with the ISOFIT method can decrease experimental time up to 80 % and reduce potential changes in muscle parameters due to fatigue.

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### 2.8.3 Mathematical considerations on Hill's Equation

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Many models of human movements use Hill's equation (Hill 1938)

$$f(v) = \frac{c}{v + b} - a \qquad (1)$$

for describing the contractile components of the muscle. $f$ denotes the force in the muscle, $v$ is the concentric contraction velocity of the muscle. The positive constants $a$, $b$, and $c$ are movement independent and therefore can be regarded as properties of the muscle. Instead of $a$, $b$, and $c$ other properties can be used for formulating equation (1), for example, the isometric force $f_{max}$, the maximum contraction velocity $v_{max}$, and the maximum power $p_{max}$. The parameters $f_{max}$, $v_{max}$, and $p_{max}$ can be expressed by $a$, $b$, and $c$, and vice versa. As the isometric force $f_{max}$ has to be positive, the dimensionless quantity $X$ defind by $X^2 = ab/c$ is always smaller than 1. The parameter $X$ is a measure of the convexity of the force-velocity relation (1) and it remains unchanged by normalization to anthropometric quantities and by normalization to the isometric force and the maximal velocity (Thaller & Wagner 2004). Many physiological quantities have a functional dependence on $X$, for example the efficiency $p_{max}/c$, or the ratio $a/f_{iso}$ which is connected with endurance (Zatsiorsky, 1995). The fibre composition of the muscle correlates with $b_n$, the constant $b$ normed to the length of the muscle (Sust et al., 1997). There is a symmetry relation between $a$ and $b$, and $f_{max}$ and $v_{max}$, i.e., exchanging $a$ by $b$, and $f_{max}$ by $v_{max}$ in an equation leads to a new valid equation. It is also possible to construct transformation rules for exchanging $f_{max}$ by $a$, $v_{max}$ by $b$, and $p_{max}$ by $c$ in any relation between the properties (Thaller & Wagner, 2004). For many applications of Hill-type models it is useful to make the mathematical relations provided by Hill's relation (1) transparent. If there is a strict mathematical relation between parameters, this relation has to appear in

the values of the parameters gained by inverse dynamics of the same measurement. So if values of these parameters gained by other methods show different behavior as theoretically expected, there must be a cause not yet included in the model. That helps to assess the values of measured parameters and their relations.

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### 2.8.4    An example of the planning of training

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There exist several strength training methods to improve the performance in different types of sport. The numerous methods differ in magnitude of resistance, speed of movement, number of repetitions, etc. The aim they have in common is to improve the properties of the nervous muscle system appropriate to the sport task (Digby, 1994, Zatsiorsky, 1995). This paper wants to demonstrate a biomechanical concept for the optimization of individual training.

Method: A modified Hill-muscle-model (Sust, 1996) describes the properties of the neuromuscular system. With this model one can determine the muscle and activation properties and make simulations of squat jumps. At one hand a configuration similar to a leg press with a force plate and a velocity measurement system allows to receive precise information of a leg extension movement. Afterwards, a nonlinear parameter identification process determines the model invariants representing the muscle properties maximum isometric force (fmax), maximum possible velocity (vmax), maximum possible power (pmax) and a parameter (A) which describes the quality of activation. On the other hand, knowing the individual muscle parameters one can make simulations of squat jumps. With these simulations it is easy to determine individually which muscle property has to be trained to reach the highest performance gain.

Simulations with individual parameters showed a clear nonlinear connection between muscle parameters and squat jump height. This means, that an increase of one muscle property can result in a performance improvement for athlete "X", but could eventually worsen the performance of athlete "Y".

Conclusion: The biomechanical method allows finding out the performance determining muscle property for the squat jump individually. It has been shown that the same change of muscle properties has different effects on the performance for different athletes. Important aims for the future will be the development of training programmes for each parameter and the development of appropriate models for different sports.

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## 2.8.5 Sensitivity of Muscle Force Estimates to Changes in Muscle Properties

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Muscle-fiber length ( ) and tendon slack length ( ) often appear as input parameters in biomechanical models of movement [1]. Unfortunately, accurate measurement of these parameters is problematic, so much so that a wide range of values can be found in the literature. The aim of this study was to determine the sensitivity of muscle force calculations to variations in the values of muscle parameters assumed in a generic model of normal human gait. The results will provide information on the validity of using generic musculoskeletal models to estimate muscle forces during movement and on how anatomical measurement inaccuracies can affect calculations of muscle force.The body was modeled as a 10-segment, 23 degree-of-freedom skeleton, actuated by 54 musculotendinous units [2]. Static optimization theory was used to calculate the time histories of leg-muscle forces for one cycle of normal walking [2]. Values of and for each muscle in the model were perturbed over the range of values represented in the literature. For each perturbation introduced in the model, the static optimization problem was re-solved to determine the changes in muscle forces predicted for walking. The results were then compared to the nominal values of muscle force obtained from the original optimization solution [3].
The maximum value of for vastus medialis, vastus intermedius, and vastus lateralis (VAS) given in the literature is 0.2883 m [4], which is 206% of the generic value assumed in the walking model. Increasing tendon slack length for

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VAS to 0.2883 m resulted in zero activation and force in VAS throughout the gait cycle (Fig. 1a). The predicted decrease in VAS force was partially compensated for by an increase in the force developed by rectus femoris. The smallest value of  for the ankle dorsiflexors (tibialis anterior and extensor hallucis longus, DFIN) for which an optimization solution was possible was  = 0.223 m, which is 86% of the generic value assumed in the model. A 14% decrease in tendon slack length for DFIN resulted in zero activation and high passive forces being developed in this muscle (Fig. 1b). During early stance, the force in DFIN was predicted to be 20 times higher than that derived from the nominal model. The smallest value of  for biceps femoris short head (BFSH) given in the literature is 0.1108 m [5], which is 64% of the value assumed in the generic model. A 36% decrease in the optimum fiber length of BFSH resulted in zero activation and high passive forces being developed in this muscle (Fig. 1c). To compensate, the quadriceps, VAS and RF, were required to develop much higher forces, particularly during stance. By comparison, decreasing the fiber length of soleus (SOL) to 70% of the value assumed in the generic model did not affect the predicted value of SOL force much (Fig. 1d). The results show that variations in tendon slack length and muscle-fiber length within the range of values reported in the literature can have significant effects not only on the calculated values of muscle forces, but also on muscle coordination prediction for normal walking. Muscles such as vasti, which are critical for normal function during stance, can be completely turned off, forcing other muscles, such as rectus femoris, to overcompensate.

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### 2.8.6    Modelling Gait to Test the Dynamic Behaviour of Knee Joints for Above Knee Amputees

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To get a better insight in the dynamics of prosthetic gait a virtual rigid body model of the human body was set up. This model should be able to simulate the behaviour of the prosthetic limb due to different movement tasks like level walking and stair and ramp descent. These simulations should help to test different design strategies before testing them on a real subject. The anthropomet-

ric data were taken from Hanavan (Hanavan, 1964). The segments were linked with one or more revolute joints according to the anatomical degrees of freedom. For the prosthetic system the inertial properties and the damping characteristics were taken from a computer controlled prosthetic system (C-Leg®). Sensors measuring vertical ground reaction forces, bending moment in the ankle, knee angle and angular velocity were implemented in the model to control the variable damping of the prosthetic knee joint. Kinematical data for the biological joints of the modelled system were taken from gait analysis. The measured joint angles were not applied directly to the joints but were used as input to control loops that generate appropriate joint torques. Using this technique the joint torques can be limited to physiological reasonable values (Brugger, 2003). On the other hand this leads to a certain variability in the gait patterns that is also present in the measured data and allows adding additional movement task like transition from level walking to ramp descent or placing the feet near predefined positions on a stair during stair descent. Different damping characteristics and control strategies were tested to enhance the gait patterns with respect to better symmetry and enhanced initiation of the swing phase, avoiding the "stick"-effect. Simulations showed that further enhancements may need a modification in the prescribed kinematics of the biological joints. First validation tests for the new control strategies confirmed the above findings.

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### 2.8.7    Calculating muscle length from gait kinematics accurate enough?

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Keywords: gait analysis, kinematics, biomechanics, segment length, muscle length

In patients with cerebral palsy gait analysis is often used for planning the surgery or conservative treatment. Skin mounted markers are used for calculating joint angles, joint kinetics and muscle length. Specially if hamstring lengthening is addressed by calculating hamstrings length the question of accuracy should be in mind. We performed 3-D gait analysis on a group of patients with lower extremity deformity (length discrepancy, rotation, axe deformities).From this measurement  we calculated the segment length of the shank and thigh segment

over the gait cycle. X-ray measurements were performed routinely for each patient and were used to measure the real segment length. The segment length from gait analysis showed an aberration up to 5 (13) percent of the real segment length. So calculating the muscle length from gait kinematics should be used carefully due to the variability of the segment length.

# 3 <u>Poster Presentations</u>

## 3.1 Neuroscience/ Movement Control

### 3.1.1 Aging and Concurrent-Task Performance: Cognitive Demand and Motor Control

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Researches on aging and motor control suggest that concurrent-task performance is affected by advancing in age, but that the locus of this age-related deficit may depend on the characteristics of experimental situations (Crossley & Hiskock, 1992; Kemper, Herman, & Lian, 2003). Performing at the same time a motor task and a cognitive task causes problems for older people. However, whether this age-related deficit is located to the motor performance or to the cognitive performance, depending on task difficulty is not yet clear. The purpose of this study was to test if performing a fine motor-control task concurrently with a cognitive task will lead to a greater dual-task cost for older adults than younger adults, as a function of the motor task difficulty. We also examined whether the locus of this dual-task cost is on the cognitive performance or on the motor performance, and if this locus differ as a function of age. Eighteen young and 18 healthy older adults performed a motor task that requires fine control of upper limb movements and a cognitive task that requires executive processing, first performing them separately and then concurrently. The motor task required participants to tap alternatively on two targets, the sizes of which varied systematically accordingly to Fitts' law. Performance was evaluated by Movement Time and error data. The cognitive task required participants to generate a series of random numbers at fixed production rates. Performance was evaluated through various indexes evaluating the deviations from randomness. Results showed that participants' performance on the motor task decreased slightly from single to concurrent-task condition, and that this minor motor dual-task cost was age-independent. However, older adults showed large cognitive dual-task costs. These cognitive dual-task costs in older adults appeared since the easiest concurrent-task condition and were not affected by motor task difficulty. On the other hand, younger adults' cognitive performance was not affected by concurrent task demands. In conclusion, the study showed that healthy older adults can maintain their motor-control performance under concurrent-task conditions as efficiently as younger adults but to the detriment of their cognitive performance. This strongly suggests that sensory-motor aspects of

behaviour are increasingly in need of cognitive control and supervision as we age (Lindenberger, Marsiske, & Baltes, 2000). These results are discussed in light of the permeation model developed by Baltes and Lindenberger (1997).

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### 3.1.2    Functional Integration of Supra-postural Tasks on the *Gyro*

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Scope: Postural control is not an autonomous system. It is integrated into a specific functional context, which is determined by tasks or goals that are superordinate to the control of posture (Stoffregen et al. 2000, c.f. Mitra, 2004). Krampe et al. (2003, 211) claim that humans have only a limited capacity of cognitive resources. Their experiments have shown that especially elderly people spent an increasing amount of their cognitive resources on motor control (cf. Woollacott; Shumway-Cook 2002). Our goal was to find out, how supra-postural tasks influence the coordination of 1st and 4th grade students of a primary school. Method: The participating students (class 1: N=21; class 4: N=20) underwent several trials. During the first and fourth trials the students were asked to maintain standing balance on an ankle-exercise board. In the second and third trials, the students executed extra tasks, while standing on the gyroscope. One task involved mental arithmetic, while in the other task subjects searched for and counted symbols within a block of text. The duration of each trail was 45 seconds, during which data were collected from the gyroscope. We evaluated body sway through the quotient of the time the child stood on the gyroscope (t $_{Bal., netto}$, [s]) and the deviation of the angular rates $(RMS_{phi, theta, psi.}$ [°]). We assessed cognitive performance twice, once during stance on the gyroscope and a second time while the student was seated. Cognitive performance

was judged by the average time and the relative error.

Results: The performance of postural control 1st and 4th graders was influenced by the visual search task. An ANOVA (Grade: 1st vs. 4th; sequence: arithmetic vs. searching) revealed main effects for age and task (F(1,35)=23,633; p<0,000). Stability was greater during the search task. Mental arithmetic has no effect on stance (post-hoc-test: Scheffé). The reduction of body sway, during the performance of a visual supra-postural task, is consistent with the idea of functional integration. Cognitive performance did not differ between standing and sitting conditions (error$_{rel.}$: searching= 2.96 vs. 3.12; arithmetic (only 4th grade!): 0,68 vs. 1,08). Postural control was not an end in itself: *Dexterously balancing can facilitate visual performance*!

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### 3.1.3     Adaptation to combined centrifugal and Coriolis forces depends on the number of targets.

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The human sensorimotor system adapts well to Coriolis force, but adaptation is substantially degraded when centrifugal force is present as well (Lackner & DiZio, 1998; Bourdin et al., 2001). Since those studies used a single target, we now investigate adaptation when subjects respond to multiple targets. 29 humans were seated in a centrifuge 70 cm off the axis, facing outwards. They executed outward pointing movements to targets in 1, 3, or 7 directions, located 30 cm from a common starting point; each target was flashed for 150 ms in otherwise complete darkness, i.e., subject had no visual feedback about their responses. 42 movements were executed before and after, and 63 responses during rotation at 20 rpm. 2-D finger paths were registered with the Hamamatsu

motion monitoring system. Effects of Coriolis force were registered as lateral deviations, and those of centrifugal force as amplitude errors. At the onset of rotation, lateral deviations abruptly increased. They remained high in the 1-target condition, decreased slowly in the 3-target, and quickly in the 7-target condition. When the rotation stopped, aftereffects were least persistent in the 1-target, and most in the 7-target condition. Movement amplitude decreased at the onset of rotation (i.e., an over-compensatory change), and largely normalized later during and after rotation. Movement timing was little affected by the rotation. Our findings confirm that in presence of centrifugal force, adaptation to *Coriolis* force is small when subjects point at a single target. However, adaptation improved as the number of targets increased, which suggests that the sensorimotor system established a more efficient compensatory strategy when it was allowed to sample a larger part of the force environment. In contrast to the small or gradual adaptation to Coriolis force, adaptation to *centrifugal* force seems to be extremely fast, since it was over-compensated already during the first movement under rotation. This overcompensation might reflect postural strategies (on a rotating platform, an outstretched arm is destabilizing). The observed difference between adaptation to Coriolis and centrifugal force indicates the existence of distinct mechanisms.

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### 3.1.4 A morphological analysis of finger movements during piano playing.

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Scope: Piano playing is a learned ability which links hand and finger movements in a complex and well-codified pattern. In the present study, finger movement patterns were analyzed in pianists of different experience. Methods: Sixteen pianists (4 females; 12 males, aged 8-69 years; all professionals with 2-62 years of experience) played 16 measures of a minuet by Bach. The three-dimensional coordinates of their right hand fingers were obtained by a motion analyzer (1). The 3D velocity of the fingers was determined, and a unitary kinetic energy (squared velocity by a unitary mass, $kg \cdot m^2 \cdot s^{-2} \cdot kg^{-1}$) computed. Total kinetic energy was divided into useful (vertical displacement during key

press) and erratic (extraneous movements). The pianists were divided into two groups: concert players (6; 40 years of experience on average) and students and teachers (10; 16 years of experience on average), and compared by Student's t. Results: On average, the concert players used more total kinetic energy (180.4 vs. 96.8, p = 0.026) and erratic energy (163.1 vs. 85.7, p = 0.024) than the students and teachers, while the useful energy was similar (17.3 vs. 11.2, p > 0.05). In students and teachers, erratic energy decreased as a function of experience (r = -0.381), while it increased in concert players (r = 0.555). The percentage of useful and erratic kinetic energy did not differ between the two groups (useful: 11% students and teachers, 10% concert players), but an opposite trend was found: percentage useful energy decreased as a function of experience in concert players (r = -0.958, p < 0.01), while it increased in students and teachers (r = 0.136). In conclusion, the same piano exercise was performed with different movement patterns, with some relationship to the pianist experience. During playing, the pianists can leave the non-performing fingers in contact with the keyboard, or they can lift them away from the keys, thus producing a higher force (2). The patterns of extraneous finger movements during playing could be investigated to assess their usefulness during learning (3), and to analyze the influence of personal "interpretation" on sound production.

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### 3.1.5    Imagining the big toe: Learning and bilateral transfer

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Motor imagery may facilitate the execution of a movement. Several studies found evidence for this (Feltz & Landers, 1983; Driskell et al, 1994). However, little is known about the mechanisms causing the effects of motor imagery. We conducted a study to gain insight into these mechanisms. The study consisted of two parts. The first part examines the effects of mental practice in learning a totally novel movement, the abduction of the big toe. In two experiments subjects had to physically or mentally practice the target movement with the dominant right foot. Subjects who were initially unable to abduct the big toe, absolute zeros, participated in the first experiment; subjects who could already abduct the big toe, already doing-its, were included in the second experiment. The results show it was not possible to learn a totally novel movement by mental practice, but the already doing-its improved by mental practice. The results of this repli-

cated study are similar to the results of the study of Mulder et al (2004) and emphasize the role central mechanisms may play in mental practice. It seems that motor imagery results from the utilization of stored representations of action. To explore the content of a representation we studied in the second part the bilateral transfer of the toe abduction skill to the left untrained foot. Does a representation contain muscle specific information or does it contain abstract information? Like Park & Shea (2002), we suggest that a centrally stored abstract representation is present for various muscle groups. The results show a slightly improvement in toe abduction of the left foot in the practice groups which also improved in the first part of the study. However, we only found a significant improvement in the already doing-its who physically practiced the movement. So it seems that -at least during physical practice- a representation is active that uses abstract information.

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### 3.1.6 Allocentric and Egocentric Visual Cues Influence Online Grasping Control: Evidence from a Pictorial Illusion Study

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Pictorial illusions such as the Müller-Lyer (ML) figure reliably influence perceptual judgments of object size; however, there remains vigorous debate as to whether pictorial illusions similarly influence visually guided actions (cf. Heath et al. 2004 vs. Glover and Dixon 2002). Hence, the present investigation asked whether the online control system is influenced by the context-dependent properties of the ML illusion. In advance of a closed-loop grasping response, participants (N=15) formulated a stable grip aperture (SGA) based on the size of a graspable 3, 5, or 7 cm object presented in a neutral visual background. Following SGA formation, vision of the grasping environment was withdrawn for 2 s (via liquid-crystal shutter goggles). During the occlusion interval, participants maintained SGA while the experimenter replaced the neutral preview object with a graspable 5 cm target object embedded within a fins-in or fins-out ML

configuration. After the occlusion period, vision was returned and participants were cued to modulate SGA online to accurately grasp the target. We reasoned that the SGA formulated for the "too small" (3 cm), "veridical" (5 cm), or "too large" (7 cm) preview objects might provide a novel opportunity to examine the degree to which the visuomotor system engages allocentric and/or egocentric visual cues for online grip aperture (GA) modifications. Grasping time (GT) was normalized and GA data were subjected to Time (20%, 40%, 60%, 80% of GT) by Preview Object (3 cm, 5 cm, 7 cm) by Illusion (fins-in, fins-out) repeated measures ANOVA. Not surprisingly, the preview objects reliably influenced GA from 20% to 60% of GT; however, at 80% of GT the differently sized preview objects no longer influenced GA. Most notably, the unfolding grasping response was influenced in a direction consistent with the well-documented perceptual effects of the ML figure. Thus, and in spite of the differently sized preview objects, GA for the fins-out ML figure was greater than the fins-in ML figure from 20% to 80% of GT. We have interpreted this result to reflect the fact that the visuomotor system incorporates contextual features surrounding a target when affecting online corrections. Indeed, such an interpretation is congruent with recent evidence arguing the aggregation of allocentric and egocentric visual cues in the online control of goal-directed actions (Krigolson and Heath 2004).

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Heath M, Rival C, Binsted G (2004). Can the motor system resolve a premovement bias in grip aperture? Online analysis of grasping the Müller-Lyer illusion. Exp Brain Res 158: 378-385

Krigolson O, Heath M (2004) Background visual cues and memory-guided reaching. Hum Mov Sc (in press)

### 3.1.7    Non-conscious planning and control: Masking the movement goal.

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An influential theory in the action-perception literature suggests that the online control of reaching movements occurs independently of conscious experience (e.g. Goodale et al. 1986; Pelisson et al 1986), indicative of a non-conscious dorsal "action" visual stream (e.g., Blouin et al. 1995). The current investigation examines the role of covertly presented information on the preparation and control of goal-directed actions – both generally considered dorsal functions. In experiment 1, visual backward masking was used to subliminally present primes

predictive of the upcoming motor response. Two target arrays (one, two or three horizontally aligned circular targets) were presented on contralateral sides of a home position. An arrow primed both the direction and complexity of the up-coming movement – and was subsequently masked. Subjects were to generate a single, double, or triple segment aiming response in response to a tone; one array disappeared concurrent the start tone thus specifying the complexity of the required movement. Despite subjects not experiencing conscious awareness of the masked stimuli, movements were prepared using the complexity prime inde-pendently of the direction prime. A planning deficit was associated with incom-patible complexity primes, as subjects covertly prepared and activated the primed movement response. In the event of an overly complex program (i.e. prime 3 segment, cue 1 segment), the subject prematurely ended the movement response – still incurring the planning delay. When an insufficient program was delivered, the program was appended online to generate the correct (cued) movement sequence. In experiment 2, participants were presented a target at one of two locations (28 cm amplitude, ±5° from midline); the target was then per-turbed to the opposite side of the midline and subsequently masked. In order to examine the time-course of movement preparation more closely, perturbations occurred at each of 4 times: 2 seconds prior to the start tone, concurrent with the start tone, concurrent with movement initiation, and 150 ms following move-ment initiation. Once again, participants were unable to consciously detect the masked stimuli. Consistent with the conscious experience participant move-ments always terminated at the initial target location. However, kinematic and temporal markers early in the execution demonstrated marked effects of the masked target location. In particular, when perturbations occurred prior to movement initiation, the initial segment of the movement was directed at the primed location. Taken together, the finding from these studies suggests a more complex interplay between conscious awareness, visual processing, and the preparation of movements.

### 3.1.8 Mental isochrony: Reality or imagination?

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There is experimental evidence that a temporal overlap exists between the actual performance of a movement and the mental imagination of that movement. This overlap has been shown in a number of studies. In the present paper it is argued that the experimental design that was employed in these studies may have influ-enced the findings. In these studies mental imagination followed the actual per-formance of a movement. This may have created a 'memory overflow" effect.

Therefore, in the present study a different design was employed to avoid the effect of a specific order of conditions. In the experiment 18 subjects executed and imagined 3 different writing tasks. The durations of the imagined and executed movements differed significantly for all three tasks, although they correlated. So, no fully mental isochrony effect could be obtained. These findings indicate that there is central activation during motor imagery, but that this does not mean that motor imagery and execution have identical output characteristics.

Decety, J., & Michel, F. (1989). Comparative analysis of actual and mental movement times in two graphic tasks. Brain and cognition, 11, 87-97.
Jeannerod, M. (1994). The representing brain: Neural correlates of motor intention and imagery. Brain and behavioral sciences, 17, 187-245.
Papaxanthis, C., Pozzo, T., Skoura, X., & Schieppati, M. (2002). Does order and timing in performance of imagined and actual movements affect the motor imagery process?: The duration of a walking and writing task. Behavioural brain research, 134, 209-215.

### 3.1.9 Control of racket motion in a rhythmic ball-bouncing task

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This study aims at understanding the mechanisms underlying successful performance in the rhythmic bouncing of a ball. Bouncing a ball to a specified target height requires that the movement of the hand be synchronised with the ball. The latter has to be hit at the right time at the right place and with appropriate velocity. When subjects are asked to perform the task repeatedly, the effector motion is oscillatory and can be characterized by a limited number of controlled variables. Therefore this task raises questions about the relationship between perceptual information and motor control. Ball bouncing can be modelled as a dynamical system at equilibrium. Schaal et al. (1996) modelled this task as a surface moving periodically up and down and hitting the ball whose trajectory is governed by the laws of ballistic flight (gravitation constant g) and elastic impact (coefficient of restitution $\alpha$). They showed that the system is dynamically stable when racket acceleration at impact is negative within a limited range that depends on g and $\alpha$. In other words, if subjects keep hitting the ball with racket acceleration in this range, they will easily succeed in maintaining the ball amplitude constant. When g and $\alpha$ have normal values (9,81 m/s² and 0.42), it was previously shown that human subjects are indeed guided by these stability properties. The aim of the present work was to shift the stability range by changing g or $\alpha$ (across or within trials) and to observe whether subjects are able to regulate the effector motion in order to find the "new" system attractor. A virtual reality set-up allowed us to manipulate g, $\alpha$ and target height

H. Thirteen subjects participated in three experiments, during which either g, α, or α and H were modified. Subjects held a real table-tennis racket, whose position in space was captured at 120Hz by an electromagnetic motion tracker. They stood in front of a large screen and controlled a virtual racket that could impact a vertically moving virtual ball. Preliminary results indicated that participants tend to bounce the ball with negative racket acceleration. ANOVAs showed that racket acceleration at impact increased significantly when g increased ($F(4,48) = 9.63$, $p<0.05$), whereas it decreased significantly when α increased ($F(4,48) = 5.12$, $p<0.05$). Other racket kinematic variables were modified, which will be further analysed and related to subjects' performance in the task.

Schaal S, Atkeson CG, Sternad D (1996) One-Handed Juggling: A Dynamical Approach to a Rhythmic Movement Task. J.Mot.Behav. 28: 165-183

### 3.1.10    Monocular grasping is more sensitive than binocular grasping to the Muller-Lyer illusion

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Early reports that visually-guided grasping actions were refractory to pictorial illusions (Aglioti et al., 1995) generated much excitement in the cognitive neuroscience community. Although numerous studies have replicated these early findings, many others have failed to find evidence for this so-called perception-action dissociation. In short, it appears that the independence of visuomotor and perceptual processing in normally-sighted individuals depends on the parameters of the task under investigation. One of these parameters might be whether the task is carried out in binocular versus monocular viewing conditions. It has been suggested that the ability of the visuomotor system to resist illusion-inducing contexts depends on the availability of binocular cues to object distance. According to this argument, when binocular cues are available, the object's retinal image can be accurately calibrated to determine absolute object size. Despite the obvious theoretical importance of this hypothesis, it has been the subject of suprisingly few empirical studies. Marotta et al. (1998) and Otto-de-Haart et al.(1999) reached different conclusions about the relative sensitivity of monocular and binocular grasping to pictorial illusions. In our current study, we attempted to bridge some important methodological differences between these two studies by studying the effect of the Muller-Lyer (ML) illusion on open-loop grasping movements in monocular and binocular conditions while either holding object distance constant for a set of trials, or randomly varying object distance within a set of trials. Results show that although the ML illusion

affected grasping in all situations, the effect was significantly greater for monocular as compared to binocular conditions. Importantly, this effect was independent of whether or not object distance was held constant across trials. These results suggest that the resistance of action to pictorial illusions is due (in part) to the processing of binocular cues by the visuomotor system.

### 3.1.11 Interference between adaptive processes depends on their direction

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It is well established that sensorimotor adaptation is degraded when subjects are exposed first to one, and then to a different distortion. This interference is small when the two distortions differ with in their physical nature (visual vs. mechanical) *and* their kinematic coupling (to hand position vs. velocity). The interference is larger when the distortions differ in only one of these factors, and largest when they don`t differ in either factor (Bock, 2003). The present study investigates the role of a third factor, the direction in which the discordance acts. 32 Subjects pointed with their unseen arm at visual targets, using center-out-and-back movements. Finger position was registered by the Fastrak ® system at 100 Hz., and was used to provide visual feedback as a cursor. After a baseline phase with veridical feedback, we introduced a position-dependent CCW or CW distortion ($P^+$ or $P^-$), or a velocity-dependent CCW distortion ($V^+$). Depending on subject group, the order of distortions was $P^+V^+$, or $P^-V^+$, or $V^+P^+$, or $V^+P^-$. Thus, each subject was exposed to two successive visual distortions with different kinematic coupling, which acted *either in the same or in opposite directions*. Subjects` performance was quantified as the angular error of responses at the time of peak velocity. Angular errors increased at the onset of each distortion, and then gradually returned towards baseline. If compared to naïve subjects, errors during adaptation to $V^+$ were higher in subjects which were pre-adapted to $P^-$, and lower in those pre-adapted to $P^+$. Again compared to naïve subjects, errors during adaptation to $P^-$ were higher, and errors during adaptation to $P^+$ were lower in subjects which were pre-adapted to $V^+$. Our data show that two adaptive processes with different kinematic coupling yield interference when they act in opposite directions, but facilitation when they act in the same direction. When considered together with previous work (see above), our findings suggest that the *magnitude of interference or facilitation depends on the similarity between previously learned and newly required responses*. If so, the observed interference would simply quantify by how much the responses have to change, irrespective of their physical nature and kinematic coupling.

O.Bock (2003) Sensorimotor adaptation to visual distortion with different kinematic coupling. Exp Brain Res 151: 557-560.

### 3.1.12 Transformations between movement and visual space: an instance where Fitts' law does not hold

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There is increasing evidence that movement organization cannot be understood without taking the goals and effects of a movement in extracorporeal space into account (Mechsner et al. 2001). We were interested in the question, whether extracorporol (visual) space has an influence on movement kinematics in a Fitts' like task. In the present study we investigated whether Fitts' law does hold when a transformation between movement space and visual space is introduced. In Experiment 1 participants had to carry out vertical reversal movements in a continuous fashion. Movement amplitude (12 cm) and target width (0.4 cm) and therefore index of difficulty (5.91) were equal for all conditions. Nine different gain conditions were conducted in different blocks (1.8, 1.6, 1.4, 1.2, 1.0, 0.8, 0.6, 0.4, 0.2). According to Fitts' law movement times should be equal in all conditions. Thus, any systematic differences in movement time between conditions must be attributed to the influence of the visual reference frame on movement organization. Movements with higher gain were slower and had lower peak velocity than movements with lower gain. This indicates that extracorporeal space has an effect on movement kinematics and that Fitts' law does not hold across different transformations between movement space and visual space. In Experiment 2 we replicated those results investigating horizontal reversal movements and different index of difficulties. In accordance with the ideomotor principle (Prinz 1997) we suggest that distal consequences and context of movements provide a reference frame for movement organisation.

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Prinz W (1997) Perception and action planning. European Journal of Cognitive Psychology 9:129-154.

### 3.1.13 Evidence for voluntary processes involved in the control of human walking by using a dual task paradigm

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Keywords: Dual Task - Walking – Control – Human - Interference
Introduction- The aim of this study was to investigate the role of cognitive factors in the control of steady state of walking. Method- A dual task paradigm was

used. A reaction time (RT) was measured in 10 healthy subjects, 18 individuals post cerebral vascular accident (CVA) and 7 incomplete spinal cord injured people (SCI) under the following conditions: sitting backwards standing and walking on a treadmill, with a simple (experiment 1) or a complex (experiment 2) RT. In addition, pressure sensors were placed under each shoe to examine phase-dependent modulation of the RTs. Results- *Experiment 1*: Walking resulted in a significant increase in mean RT compared to sitting and standing conditions in individuals post CVA (Friedman, $p<0.0001$) or SCI (Friedman, $p<0.004$) whereas no effect was observed in Healthy subjects. A sub group has been identified in hemiparetic subjects: 9 patients (H-group) had a longer RT in sitting position and 9 (H+ group) had a RT included in the confidence intervals of mean performance (95%) of non-disabled adults. A significant linear relationship was found between walking speed and RT in H- subjects (test Theil, $p< 0.0023$) but was no significant in H+, SCI and healthy subjects. While subjects walked on the treadmill, phase dependent modulation of the RTs was found. In healthy and SCI subjects, RTs were significantly longer during the transition from double limb support phase to single support phase whereas post CVA subjects showed an increase in RT during all changes in gait phases. *Experiment 2*: A 2 (simple or complex TR) x 2 (sitting or walking) Anova with repeated measures was used to examine between and within differences RT in healthy subjects. There was a main effect for walking ($p<0.03$) and complex conditions ($p<0.0001$) on RT with no interactions. Discussion- Interference between steady state of walking and RT was observed in both subjects indicating that human walking is not an automatic motor act. The phase dependent modulation of the RTs suggests that voluntary processes are important in the control of the step cycle. The increase of attentional demand for walking may be related to the gait impairments but also to the general reduction capacity after brain damage. Interference between cognition and locomotor task may be important in assessing neurological patients' difficulty to walk.

### 3.1.14   Sensorimotor adaptation to visual versus acoustic distortions

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The central nervous system can gradually adjust to various sensorimotor distortions. A number of studies have documented the transfer of adaptation to the unpractised arm, which was taken as evidence that adaptation is localised in the sensorimotor system upstream of the divergence point for left and right arm control [1]. In contrast, a transfer of adaptation from a trained to an untrained sensory modality has only been addressed by a few older studies, which yielded controversial results [2,3]. It therefore remains unclear whether adaptation is

localised before or after the convergence point of sensory modalities. This question is addressed by the present work. 24 subjects pointed at targets arranged along a semicircle 12 deg apart, without seeing their arm. Their index fingertip position was registered contact-free, and could be used to provide feedback about the momentary finger position. In one half of the subjects, we used visual targets and visual feedback (light spot); in the other half, we used acoustic targets and acoustic feedback (tone pitch). In each sensory modality, subjects adapted either to a 30 deg rotated, or to a 50% scaled feedback of actual pointing direction. All subjects adapted to the distortions. The magnitude of adaptation was larger in the visual than in the acoustic modality. However, the persistence of adaptation after removal of feedback was not modality-dependent, which suggests, that the advantage of the visual system is mainly due to strategic factors. Intersensory transfer was quantified by asking the adapted subjects to point at targets in the untrained modality without feedback: the magnitude of transfer, normalized to the respective level of persistence, was substantially larger from visual to acoustic targets (mean: 77%) than from acoustic to visual ones (mean: 26%). This second advantage of the visual system is most likely not due to strategies. The observed modality-dependence of transfer argues against a single locus of adaptive mechanisms in the sensorimotor system. This work was supported by DFG (BO649/8) and BMBF (50WB9942/6). Responsibility for the contents rests with the authors.

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### 3.1.15 Cognitive load and training of exaggerated isometric force production in high-G

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Our earlier work has shown that subjects exposed to an increased gravity (high-G) produce exaggerated isometric forces in all directions of three-dimensional space. The present work was designed to examine, whether force production in high-G has an increased cognitive load and whether training reduces the G-related exaggeration of force. Using an isometric joystick, healthy volunteers reproduced visually prescribed force vectors of eight different directions and three different magnitudes (5, 15, 25N) with their unseen dominant hand. With

their other hand, they performed a visually presented four-choice reaction task. In each test sequence both tasks were performed separately and under dual-task conditions. 12 healthy volunteers carried out a first sequence in normal terrestrial gravity (1G), a second at the onset of three times terrestrial gravity (3G), and a third after a training of about 12 minutes with visual feedback still in 3G. A control group of 12 volunteers carried out the whole experiment in 1G. At the beginning of 3G, subjects produced significantly exaggerated forces in comparison to 1G, both in single- and in dual-task conditions. The average overshoot was about 14N. After training, force production in 3G decreased to the same level as in the 1G control group. Produced forces as well as reaction times were higher under dual-task conditions, but this difference was not dependent on G-level or training. Our findings confirm that isometric forces are exaggerated in high-G. They further show that this problem can be overcome by extensive training. Our dual-task data indicate that exaggerated forces are not due to an increased cognitive load in high-G. Instead they may reflect a facilitative role of descending vestibulospinal signals, which can be overcome by training. Our results might be relevant for the design of training sessions for jet pilots, since accurate force production is important for their safety during high-G manoeuvres.

### 3.1.16   Pointing with a stick is disrupted in apraxic patients.

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Apraxia is a bilateral impairment of complex gestures following left-brain injuries in right-handed individuals. Apraxic patients have a disruption of tool use due to impairments of knowledge on tool and action properties and/or of movement execution adaptation. Simpler movements as pointing are classically preserved but pointing with a stick has not been investigated previously. The motor system must incorporate the stick, so that its tip (the Working Point WP) becomes the part of the limb-tool complex that is specifically controlled as shown by its regular and smooth trajectory. Recent studies in monkeys and humans evidenced that incorporation of a tool into the perceptual representation of the limb was elaborated bilaterally in the contralateral parietal lobe. The question is whether or not the lateralised cerebral areas that are injured in apraxic patients are involved in the incorporation of a stick into the movement. To that purpose we examined 10 apraxic (8 with left brain damage and 2 degenerative) and 10 control patients with left brain damage. All were right handed and pointed with their left side under 3 conditions (with the index, a short or a long stick) at 3

targets located at different normalized distances in the sagittal plane. 10 movements were performed in each condition. The movements were recorded at 40 Hz with three electromagnetic Polhemus sensors fixed respectively on the stick (or finger), the hand and the acromion. The trajectory of the WP was calculated from its local coordinates in the first sensor frame. All the control LBD patients pointed smoothly and accurately whatever the condition, demonstrating that they anticipated the geometry of the limb, tool and task constraints. By opposition, 6/10 apraxics, showed marked abnormalities when pointing with a stick (abnormal strategies, abnormal errors, irregular velocity profile) thus demonstrating a lack of anticipation and adaptation to the task's constraints. This might be compensated, at least in part, by learning processes. The other 4 patients made qualitatively normal movements but less smooth and accurate than control patients. There was no clear relationship between lesion location (including or not the posterior parietal lobe) and behaviour.

In conclusion, apraxic patients might have a selective impairment in stick pointing. This suggests that the left cerebral hemisphere may be also dominant for the incorporation of a simple tool into the coordination of the movement. This specific impairment might explain some of spatio-temporal perturbations observed in apraxics' movements.

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### 3.1.17  Effects of cognitive vs motor secondary task on gait in mild PD patients

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Previous studies showed patients with idiopathic Parkinson's disease (PD) had poorer gait performance in dual-task conditions when comparing to that of walking only and when comparing to that in the healthy elderly with walking in dual-task conditions.  Results of these studies were assumed to reflect that the attention demands on the cortex were increased with the impaired basal ganglia for motor performance in patients with PD.  But the effects of a cognitive versus a motor secondary task on gait were reported quite inconsistent among these studies. The purpose of this study was to compare the interference effects of cognitive versus motor secondary tasks on temporal-distance gait in patients with mild idiopathic PD. Instrumental gait analysis was performed in 21 sub-

jects with mild idiopathic PD while they walking and performing a secondary task simultaneously: (1) a cognitive secondary task by counting backward aloud in multiples of three, (2) a motor secondary task by making opposition of the thumb to the second, third, fourth, and fifth fingers, and (3) a motor secondary task by clapping alternately with a clapper in each hand. The results of this study showed adding either a cognitive or motor secondary task changed significantly (p<0.05) the speed, cadence, stride length, and percentage of the gait cycle in single-leg-support of subjects with mild idiopathic PD from their free walking. Significant differences (p<0.05) of interference effects on the aforementioned gait variables between cognitive and either one of the motor secondary tasks were noted, but differences of interference effects on these gait variables were not found between two types of the motor secondary tasks, in subjects with mild idiopathic PD. Our results demonstrated that the cognitive versus the motor secondary tasks had distinct effects on temporal-distance gait even in the patients with mild idiopathic PD.

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### 3.1.18 Efficient Learning Control of Dynamic Point-To-Point Movements

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Motion control of articulated structures such as humans/humanoid robots is challenging due to the great number of joints and muscles and the complex actuator and structural dynamics. A very important question is how such multibody systems (MBS) can be efficiently controlled in dynamic motion tasks like reaching, standing-up, walking, or running. Positioning accuracy, movement execution time and energy consumption are considered as main dynamic performance indices in such point-to-point movements (PTPM). Taking into account also the existing control constraints, one finds that some rather complicated performance optimization problems are to be solved. On the other hand, MBS are highly nonlinear dynamic systems and model-based control synthesis techniques are very likely to be inefficient. In the present study, a conceptual framework for efficient learning control of dynamic PTPM is developed, [1].

Our learning control approach has the following main steps: 1) Take properly parameterised test control functions that conform to the time/energy optimality criteria; 2) Define the most appropriate pairs of control parameters and controlled outputs; 3) Solve shooting equations and perform motion optimisation applying fast converging iterative techniques. The proposed approach is with the necessary mathematical guarantees for its feasibility. It has also the following advantages: only a few decision parameters for a control function are used and the optimisation procedure converges within minimum number of trials. It is found also that, according to several recent studies on control of human voluntary movements, our learning control scheme proves to be a biologically plausible one, [2]. A modular program system with a user-friendly interface is designed to solve PTPM for various-type controlled MBS, [3]. Two main dynamic models have been tested: a two-link robotic manipulator and a mobile robot with two independently driven wheels. The computer simulations show that the corresponding PTPM problems can be easily and quickly solved with the necessary accuracy. In the above considerations, no obstacles for the MBS motion were assumed. If this is not the case, we can properly decompose the motion task into several PTPM problems having no geometric constraints. As an interesting example, we consider how a bipedal robot can be learnt to perform steps. Dynamics-based simulations will be presented as well. The proposed learning control approach is biologically motivated and as such it has the potential to be applied to various human motion tasks in sport, rehabilitation, and other biomechanical problems, where voluntary movements have to be performed.

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### 3.1.19 Oculo-manual coordination in a continuous rhythmical pointing task

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Precise coordination between eyes and hand is necessary for a correct execution of arm tracking or pointing tasks (Lazzari et al. 1997). In continuous rhythmical

movements (like the Fitts' task), the intrinsic kinematics of the oculomotor system (latencies between saccades, smooth pursuit limited maximum speed, etc.) is potentially a limit for the execution of the task at high frequency, i.e. at low difficulty levels. The purpose of this work was to demonstrate the reciprocal influence of eyes kinematics on hand kinematics during the execution of a Fitts' task with different indexes of difficulty (ID). It has been previously shown that varying the difficulty not only affects the movement time but also arm trajectory (Mottet & Bootsma, 2001): at lower IDs, the arm moves at higher frequency and the trajectory becomes sinusoidal. Six subjects had to complete a rhythmical pointing task, with ID varying from 2 to 7, under two different conditions: eyes free to move (condition S) vs. eyes looking at a fix point between the two targets (condition F). Both conditions were executed twice for each ID, in a pseudo-random order. The results showed that the effective ID (IDe) was significantly different between the conditions (p<0.001). While keeping the eyes fixed in the middle of the targets, subjects performed with their arm at lower IDe than when the eyes were free to look at the targets, showing a direct influence of eye movements on arm speed-accuracy trade-off. This difference was remarkable for IDe higher than 4.25, while at low IDe the two conditions did not differ. This could be due to a lesser precision in F condition for high IDs and to a lower speed in S condition for low IDs. This interpretation is coherent with Abrams et al. (1989) who proposed that accuracy was dependent on task difficulty. Moreover, an analysis of the saccadic frequency (Fe) and the hand frequency (Fh) showed that for IDe higher than 4.25 the frequency ratio Fe/Fh was 1, while it dropped down for IDe lower than 4.25 (the subjects produced lesser saccades that arm movements). This break point corresponded to a frequency of about 1.4 Hz. It has to be noted that eye and arm movements are reciprocally affected at the same IDe level. The disruption of saccade frequency is probably due to the high energetic and attentional cost needed, related with the relatively low informational benefit when ID is low. Loosing the 1:1 eye-hand frequency ratio, subjects performed eye movements with lower frequency ratios (1:2, 1:3, etc) in order to perform a kind of occasional control of the task. In summary, the saccadic and the arm motor systems reciprocally interact during the execution of a Fitts task. At IDe values lower than 4-4.5, arm movement frequency tends to be too high for the saccadic system and visual information about target location of lesser importance, hence allowing intermittent visual control.

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### 3.1.20 The appearance of temporal invariance in the formation of skilled, quick, discrete movements

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Bernstein (1967) taught that a full understanding of human skilled performance awaits an account of how the motor system controls coordination among the many degrees of freedom necessary for smooth, efficient, and effective actions. A fundamental assumption in the area of motor control is that movements are organized centrally in the form of motor programs (Henry, F. M. and Rogers, D.E. 1960). Schmidt proposed that the central nervous system creates a sort of "master plan" (Schmidt, R.A. 1975) that can be implemented often without on-line control (Keele, 1981). According to Schmidt, a GMP controls a class of action rather then a specific movement sequence. A class of action refers to a range of different actions that have a common but unique set of features. These features can be detected as spatial and temporal invariance. This paper is dedicated to detect the appearance of temporal invariance during the formation of skilled movement behaviour. According to our hypothesis both classical (repetition) and variable practice has the same effect on the appearance of temporal invariance. We applied B. Knapp's (5 phases) skill acquisition theory to be able to differentiate the stages of learning process. We can conclude on the basis of our findings that the suggested temporal invariance by Schmidt appears only at the 4th phase of skill acquisition process at both classical and variable training group.
Keywords: motor program, generalized motor program, skill acquisition, variable training, classical training

### 3.1.21 Coordination dynamics govern the formation as well as the switching between graphic patterns of handwriting

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Handwriting is considered as a sequence of cyclic movement and results from the coordination of two orthogonal oscillators. We bear on the assumption that handwriting results from the dynamics of non-linear coupled oscillators. All

shapes of handwriting can be described by the modulation of the relative phase and the ratio of frequency between both oscillators (Hollerbach, 1981). Athènes et al. (2004) identified stable states of the underlying dynamics of two orthogonal components using a scanning paradigm. This dynamics is composed by four preferred patterns, 0°, 45, 135° and 180°, characterized by attraction properties and by a differential stability. Based on this differential stability, Sallagoïty et al. (2004) showed that under a high movement velocity or with the non dominant hand, the least stable pattern degraded steeper whereas the most stable preferred patterns kept a highly accurate and stable performance. Then, theoretically this differential stability should also govern the intentional switching from a pattern to another (Scholz & Kelso, 1990). This study aimed to identify the rules of transition between the four preferred coordination patterns of the dynamics of handwriting. Seven right-handers produced six different intentional transitions between the four preferred coordination patterns (0°, 45°, 135°, and 180°) by pairs. These patterns correspond to two strokes (0° & 180°) and two ellipses (45° & 135°) tilted to the right (0° & 45°) or to the left (135° & 180°). Each transition has been produced in two ways: from a more stable to a less stable pattern (e.g., 0° to 180°) and on the other side (e.g., 180° to 0°). Participants were instructed to produce two patterns which appeared successively in a digital tablet and to perform the second pattern as soon as it appeared without lifting the pen. For all transitions, our results showed that the time to switch from a more stable pattern was always longer than on the other side. Moreover, the switching time increased when the participants had to change the spatial direction of the produced pattern during the transition. Those results confirmed that the rules of transition between graphic patterns come from their properties of stability but are also dependant of the process of suppression and reduction of df implicated during the transition. Alike all periodic motion, graphic skills exhibit preferred patterns, nonlinear transition and predictable deterioration which corroborate that the existence of dynamics underlying handwriting comes from the dynamics of non-linear coupled oscillator.

Key-Word: Intentional switching, Attractors, Dynamic pattern theory, Nonlinear coupled oscillators, Graphonomics.

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### 3.1.22  Effects of limb vibration on sensorimotor adaptation

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Earlier studies with deafferented patients showed inconsistent findings concerning the contribution of proprioception to sensorimotor adaptation. The present work addresses this issue using limb vibration, which is known to reduce proprioceptive feedback. Subjects pointed with their unseen arm at visual targets in a center-out pointing task, using a pen-like implement. A cast restrained their movements to wrist and fingers. The instantaneous pen position was registered and displayed to them in real-time as a cursor, thus providing visual feedback about movement success. After a baseline phase, visual feedback was distorted by a 60 deg rotation about the display center in Exp. A, or a velocity-dependent force was applied orthogonally to the response direction in Exp. B. Ten of the twenty subjects in each experiment were exposed to an 80 Hz vibration of the flexor and extensor side of their wrist, using two vibrators. Subjects reported a numbness of their fingers under vibration. In agreement with previous work, pointing errors in all subjects increased abruptly at the onset of the respective distortion, and then decreased gradually with prolonged exposure. In Exp. A, vibration had no effect on the time-course of adaptive improvement. In Exp. B, however, vibration led to a reduced adaptation, associated with a larger incidence of widely deviating movement paths. Our findings suggest that intact proprioceptive feedback is required for sensorimotor adaptation to mechanical distortions, but is dispensable for adaptation to visual distortions. This outcome is in accordance with the view that visual and mechanical distortions activate distinct adaptive mechanisms in the sensorimotor system. Supported by the German Federal Ministry of Education and Research (grant 50WB9942), and by DFG (grant BO 649/8). Responsibility for the contents rests with the authors. Experiments were carried out with the full understanding and written consent of each subject.

### 3.1.23  Eye-hand coordination asymmetries in manual aiming: an fMRI study

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Keywords: eye-hand coordination, manual asymmetries, fMRI
The goal of the present experiment was to identify the neural architecture underlying manual asymmetries in eye-hand coordination. After all, there is a strong

link between eye and hand movements during coordinated manual aiming. The timing of eye and hand movements is optimal to allow for on-line feedback-based adjustments (see Starkes et al., 2002 for a review). Specifically, saccades are finished before the hand reaches peak velocity. Interestingly, in a recent study (Lavrysen et al., submitted), both left- and right-handers showed a delayed eye-fixation onset and time to hand peak velocity when aiming with the right hand as compared to the left hand, regardless of the availability of vision for on-line movement control. This coordination supports functional asymmetries, related to differences in feedforward and/or proprioceptive processing skills between both hand/hemisphere systems (Roy et al., 1994). Despite the altered arm dynamics depending on the hand being used, the relative timing of eye and hand movements was preserved. Thus, the eye-hand coordination pattern was adopted to accommodate asymmetric hemisphere specializations. It was suggested that different movement strategies are applied according to the abilities of the hand used, in order to produce the same outcome. In the present experiment, differences in performance measures and limb kinematics due to manual asymmetry effects were linked with differences in the patterns of cortical activity associated with left as compared to right hand movements. Specifically, both left- and right-handed participants performed continuous wrist flexion and extension movements with the preferred or the non-preferred hand in a 3T MR scanner. Movements were paced by an auditory metronome (2 Hz) at a fixed trained movement amplitude of 40°. Eye movements were sampled at 200 Hz with an ASL eye-tracker model R-LRO6 and wrist angular position was recorded by means of encoders fixed on non-ferromagnetic fore-arm ortheses. Five runs were performed where each of the following conditions were repeated three times: saccade condition (eyes alone), hand alone conditions (right and left), coordinated conditions (right and left hand with saccades) and rest conditions. Mainly cerebellar regions were found to be involved in coordinating saccades with hand movements.

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### 3.1.24 Motor prediction revealed by grip force anticipation of repetitive external loads

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When we manipulate objects our grip forces must stabilize against loads to prevent slippage. Loads may be self-generated and predictable such as during accelerating a grasped object (inertial load) or during pulling against a fixed resistance (isometric loads). In these situations grip force anticipates the load profile with high precision in a feed-forward control mode. A feed-back control mode must be employed, when loads are produced externally and are unpredictable. Consequently, grip force reactions are characterized by time delays in the range of 100 ms. The present study attempts to reveal changes of grip force anticipation when a novel, externally produced load profile is presented with a high repetition rate. Healthy subjects had to stabilize a hand-held object against a sinusoidal load profile with a frequency of 0.66 Hz and a load range between 2 and 6 N. The load was presented during ten 1-min-intervals separated by short breaks. A second block was delivered after a break lasting one hour.  The subjects' task was to maintain the object in a constant position. However, the main dependent variable analyzed was the grip force produced against the object surface. Subjects succeeded to regulate the grip force approximately in parallel with the load already during the first trial as obvious from high coefficients of cross-correlation. However, positive time lags between the grip force profile and the load suggested that the control-mode was largely feed-back. In addition, the inclusion of blank-intervals caused a rapid cessation of the grip force modulation. Only after prolonged practice a tendency for load prediction was obvious by decreased delays and grip force modulation during blanks. The grip force level decreased continuously during practice. We conclude, that the precision and the timing of grip force prediction develop much slower when the loads are generated externally compared to loads which are self-produced. High repeatability may induce prediction after prolonged training. Grip force anticipation is obvious by a decrease of the grip force level indicating increasing economy. This result again demonstrates the independence of the mechanisms controlling background grip force level and grip force/load force coupling.

### 3.1.25   Weight anticipation in shoulder kinematics during a grasping task

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The aim of this study was to understand the shoulder contribution in grasping objects of different weights and to search traces of anticipation in joint kinematics. Eight valid young adults participated in this study. They had to achieve 48 grasping and loading of three objects. Objects had exactly the same shape but

differed by color and weight (120g, 180g et 1000g). Subjects were instructed before the task that there was a link between the colours and the weight of objects. Kinematical data of the upper limb were collected using an electromagnetic 6D motion capture device (Motion Star). A biomechanical model of the upper limb (the Byriukova's model) allowed us to estimate instantaneous rotations of the trunk, shoulder, elbow and wrist joints during the task. This method respects the 'Shoulder Group' conventions for Euler angles. Our results show that the anticipated weights influenced movement kinematics and angular motions of joints much earlier than some authors wrote. For instance Jeannerod proposed that the grasping component is the only one to be influenced by the anticipated weight. In the Gentilucci's works, only the final approach of hand transportation was said to be linked with the weight. We found traces of anticipation as soon as during the accelerating phase of the hand transportation. We also obtained a precise description of the chronology of a proximo-distal propagation of movement in the upper limb. We noticed that the scapulo-thoracic joint was the first to move (before the hand) followed by the gléno-humeral joint. The elbow and wrist joints begin to move only after the hand. We also confirm the existence of a medial tilt supposed to set up the shoulder for the grasping movement (Bonnel 1992). The fact that weight anticipation appears very early in joints kinematics seems to support the idea that the CNS use an open-loop control of movement through a motor programming of the grasping task.

### 3.1.26 Processes involved in finger tapping task : a behavioural and electrophysiological study.

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Although many studies have investigated rhythmic motor production, its neural basis involved in this task are largely unknown. In an MEG/EEG study, twelve right-handed participants (age = 25 ± 3) underwent a rhythmic tapping task involving a synchronization phase (S) and a continuation phase (C). During the S phase participants had to synchronize their finger taps to 25 ms tones (15) delivered every 600 ms and after the cessation of tones they had to continue to tap at the same tempo (~20 taps). Both phases were performed with each hand (right hand (RH) and left hand (LH), the order was counterbalanced across participants ).

Different behavioural indices were analysed: inter tap intervals (ITIs), synchronization error (SE), coefficient of variation (CV = std/ITI), motor and clock variance (applying Wing and Kristofferson model, 1973) and tap duration (TD). There was a clear effect of the condition (S vs C) on ITIs; they were signifi-

cantly shorter in the C phase (582 ms ± 8ms) than in the S phase (599 ms ± 1ms), reflecting an acceleration of the tapping rate in the C phase. SE corresponded to an anticipation of the tap onset over the tone onset (-59 ms ± 10ms). Interestingly results showed a correlation between SE and acceleration in the C phase (r = .75, p<.05), reflecting the fact that the more participants anticipated the tap over the tone, the more they accelerated their tapping rate in the C phase. In addition, CV was lower in the S phase than in the C phase. Applying Wing and Kristofferson model, we showed a significant effect of laterality on clock variance (483ms² ± 167 RH vs 632ms² ± 232 LH), but no difference between hands on motor variance (181± 55 RH vs 185±75 LH); this is in agreement with the multiple timer model (Ivry and Richardson, 2002) and suggest that timing processes are specific to each effector system. Furthermore, a strong effect of laterality on tap duration (right TD < left TD) was found. Propioceptive afference properties may explain this difference between dominant and non dominant hand.

We are currently analysing the relationships between performances and electrical brain activity in order to shed new light on mechanisms underlying motor timing.

Keywords : finger tapping, sensorimotor synchronization.

### 3.1.27   Motor adaptation in grasping: contribution of tactile perceived object size

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When grasping an object, the maximal grip aperture (MGA) is typically scaled according to the visually perceived object size. So far, only two studies addressed the adaptive properties of this scaling principle (Gentilucci et al '95; Säfström & Edin 2004). Expanding this work, we investigate whether adaptation occurs even when object *weight* information is absent (i.e., objects were grasped but not lifted), and how adaptation is affected by different object geometries. In Exp. A, participants (n = 40) had to use the precision grip to touch wooden dowels (height: 3, 5 and 7 cm or 2, 4 and 6 cm, respectively; depth: 4,4 cm; width: 1,8 cm), always presented at a single location. Subjects were randomly assigned to four groups. In a baseline phase, all subjects saw the dowels to-be-grasped in a mirror and grasped them there (54 trials). In the subsequent adaptation phase (54 trials), the physical object size was the same as the seen one in group ES, was 1cm larger in group IS, and 1 cm smaller in group DS. We found that in all conditions, MGA scaled linearly with object size; the scaling

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factor remained unchanged in group ES, increased in IS, and decreased in DS. We therefore conclude that adaptation occurred in our experiment. Exp B scrutinized adaptation when the discrepancy between seen and felt object size was below the perceptual threshold, and strategic effects were therefore less likely to play a role. Participants (n = 27) adapted in much the same paradigm as in Exp. A, except that the size discrepancy was now just 0.5 cm, and was not explicitly noticed by the large majority of subjects. The outcome was similar as in Exp. A, suggesting that adaptation can be achieved by an unconscious updating of sensorimotor transformation rules. In Exp. C, dowel depth was reduced to 1 cm in order to increase the precision requirements. The number of trials was reduced to 36, but the experiment was otherwise comparable to Exp. B. We found that MGA again scaled linearly with object size, but no reliable adaptation of grip aperture was found. These results suggest that adaptation is suspended when computationally demanding processes are needed to meet stringent task constraints (i.e., object width).

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### 3.1.28 The Correlation Between Thresholds of Time Perception and Temporal Accuracy of Motor Control

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The Theory of Event Coding (Hommel, Müsseler, Aschersleben, & Prinz, 2001) states that perceptual and action codes overlap in a common representational domain. This leads to the assumption that abilities of time discrimination should correlate with abilities of quick and temporally accurate movement production. In this study the performance in two auditive perception tests were compared with the performance in two movement production tasks. 20 participants were tested (9 female, 11 male, average age: 31.6, SD 13.1). In perception test one participants were instructed to compare the length of two paired intervals confined by two clicks each. The differences between the lengths of the presented intervals were altered in the range from 0 ms to 200 ms while the maximum length of a single interval did not exceed 500 ms. This test revealed data about the participant's capability of temporal discrimination in the dimension of duration. Perception test two addressed the ability of identifying the quantity of single auditive events. From one up to seven isochronous clicks were presented to the participants who were instructed to count the stimuli. The interstimulus

intervals (ISI) between each of the clicks ranged from 25 to 200 ms. The time discrimination threshold was the duration of the ISI for that the participants could not report the correct number of clicks anymore. Motor test one was a sensorimotor synchronisation task. The asynchrony between fingertaps and an auditive guide signal – an isochronous puls train with an ISI of 500 ms – was measured. Motor test two measured the maximal motor-frequency of an simple bimanual movement-pattern that could be performed under voluntary control. The participants were instructed to perform fingertaps with the left and right hand alternately and deliberately increase the tapping-frequency until no further increase was possible or the movement-pattern switched involuntarily from alternate to synchronous tapping. A nonparametric rank correlation analysis showed significant correlations between the values of the perception tests and the values of the motor tasks, ranging from rho=.541, p<.02 to rho=.696, p<.001. Results were controlled for age as a moderator variable. In accordance with the Theory of Event Coding this study suggests that there are mutual interactions between representations of perceived and produced events

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### 3.1.29   Game Creativity Analysis by Means of a Combination of Variance-Analysis and Neural Networks

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In order to evaluate performance data from ball games, normally quantitative and qualitative methods are used separately. The combination of stochastic quantitative analyses and neural network-based qualitative analyses can improve the information output significantly. The stochastic approach reduces the total of recorded data to only a few statistical quantities and checks their significance by means of variance analysis. In contrast, neural networks – considering all available data to be high-dimensional points that correspond to neurons – can be used to extract specific striking features and qualitative trends on all original data (see Schöllhorn & Perl, 2002). A first project has made plain that there are a number of synergy effects from a combination of both approaches (see Memmert & Perl, under review). The initial results demonstrate that the results of game intelligence obtained using the stochastic approach can be replicated using

neural networks. Furthermore, we were able to detect additional interesting aspects that were not open to the stochastic approach. In this contribution it will be shown that the results of such an interdisciplinary collaboration are not limited to convergent tactical performance attributes, but moreover and in particular can be most useful to study creative tactical performance attributes. Therefore it was necessary to improve the process-oriented learning dynamics of neural networks, which has been done by combining the advantages of the Growing Neural Gas concept (GNG, see Fritzke, 1997) with those of Dynamically Controlled Networks (DyCoN, see Perl, 2004). The resulting modified GNG not only can map the learning process dynamically but also can detect seldom but relevant events – as e.g. creative activities are. The creative learning model of modified GNG is tested using data from a BISp-sponsored project that was run by Roth and Memmert (2003). In this field-based study, sport-specific training concepts were compared to non-specific ones, dealing (e.g.) with the game creativity of about 150 children from 3 measurement times. The divergent reference numbers were determined by means of concept-oriented expert ratings (3 evaluators) using the game-test-situation USING GAPS with two rotations each (see Memmert & Roth, 2003). Using networks allows for simultaneous processing of 18-dimensional attribute vectors (3 measurement times × 3 evaluators × 2 rotations) instead of 2-dimensional aggregated vectors – avoiding reduction of semantic structures and information. This way, by means of visual evaluation of data distribution projected to the network, the results of the field-based study can be replicated and useful information becomes available, which can hardly or not be obtained from variance-analyses. Furthermore, a first step in order to validate the net-based creative learning model is done.

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## 3.2 Psychology

### 3.2.1 Understanding motor imagery: How can mental rotation teach us something about motor imagery?

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Mental imagery is one of human's most interesting cognitive capacities. However, until recently mental imagery was a poorly understood process hard to grasp for scientific investigation. The main problem was the lack of a plausible cognitive model that clearly exposes the different processes that are involved and the neural structures supporting them. The pioneering research by Shepard and Metzler (1971) got some grip on the phenomena of mental imagery by using the mental rotation paradigm. These studies have shown that mental rotation-time of 3D-objects is proportional to the change in orientation. Extending these classic experiments of Shepard and Metzler, other varieties of mental imagery are now being investigated. One of these variants is motor imagery (e.g. imagining moving a limb). Recent studies that combine different mental rotation tasks with neuroimaging methods suggest that visual and motor rotation are two dissociable processes that depend on different neural structures (for short survey see Parsons, 2003). It seems that there is some hemispheric specialization and that the superior parietal cortex plays a key role here. This study further investigates the different processes involved in mental rotation and mental motor rotation in particular. An important question that could shed some light on the process of motor imagery is whether stroke patients that suffer from paralyses still have the ability to imagine movements of their paralyzed limb. Therefore, different types of mental rotation tasks (e.g. visual and motor rotation) were performed with stroke patients and healthy adults. The results of these experiments will be discussed.

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### 3.2.2 Implicit motor learning in discrete *vs.* continuous tasks

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Learning the regularities embedded in the displacement of a target seems easier to obtain in discrete tasks than in continuous tasks. Indeed, a lot of studies show the existence of implicit learning in serial reaction time tasks (SRT) whereas similar evidence in tracking tasks is much more limited. To solve this discrepancy, we carried out four experiments in which a standard SRT task was modified to make it increasingly similar to a continuous task. All these experiments included a training phase with a Sequence A (Blocks 1-11), a transfer phase with a sequence B (Block 12), and again two blocks of Sequence A (Blocks 13-14), and learning was assessed as the impairment in performance on Block 12. The objective of the first experiment was to examine the influence of the input device. Participants were randomly assigned to two groups: one had to react by pressing as fast as possible a key that spatially matched the location of the target on a keyboard, and the other had to move the mouse and to click when the target appeared. Results showed that both groups learned to the same extent. In Experiment 2, the size of the target was reduced in order to implement a constraint of accuracy, which seems to be an inherent feature of tracking tasks. Although this task required much more accuracy, results still provided evidence of implicit learning. In these first two experiments, the appearance of the next target depended on participants' responses on the keyboard or the mouse. By contrast, in the following experiments, the target moved independently of participants' behaviour, as in tracking tasks. Participants only had to put the pointer mouse on the target as fast as possible. In Experiment 3, the target appeared in one of 4 possible locations, and in Experiment 4, the number of locations was increased to 8 in order to make the experimental settings more similar to the displacement of a target in tracking tasks. In both experiments, the time on target was longer on Block 12 than on the surrounding blocks, thus testifying again for implicit learning. These results allow excluding several possible explanations for the difference between the two tasks. Another hypothesis that warrants further studies is that the possibility for learning to occur depends on the nature (discrete vs. continuous) of the target displacement.

### 3.2.3    Time estimation during self-motion in darkness

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Keywords : time perception, self-motion, vestibular stimulation.
Temporal information is processed by a specialized mechanism called "the internal timekeeper" whose velocity could vary (Church, 1984). In a tapping task performed in darkness, with and without self-motion, Israël et al., (2004) found that self-motion influences time perception. The means of the Inter Push Intervals (IPIs) were significantly shorter for trials with motion than without.

Treisman et al. (1990) already demonstrated a variation of the velocity of the clock when series of different frequencies were applied. It was also found that the subjects were decelerating their pressing rate in the decelerating motion trials, and were accelerating their rate in the accelerating motion trials. Self-acceleration polarity, i.e. a parameter which is detected by the vestibular organs, influences time counting but the difference in the results obtained during accelerated and decelerated trials which respectively accelerated and decelerated the internal clock is surprising. In the present work, a tapping task during post-rotatory sensation in darkness was first designed to test only the effect of the vestibular sensation on the estimation of temporal intervals. Each trial consisted in 3 phases: without motion, with angular motion, post-rotatory phase without motion. The participant tapped each second without stopping throughout the whole trial. Rotations were executed either at constant velocity (3 levels) or at varying velocity (i.e., with acceleration or deceleration).

We awaited that the slopes of the IPIs obtained during the post-rotatory phase would be a) similar to the slopes obtained during decelerated motions b) steeper than during the phase with constant velocity.

We extended our test to the estimation of longer time intervals (8 or 15 s) in order to check whether the same mechanisms are involved as in the previous "one second" task. Blindfolded volunteers were standing without motion or passively displaced and had to press a button to estimate the interval. The results showed that during motion the intervals produced were significantly longer than without motion. Discussion about the role of vestibular stimulations on time perception is given.

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### 3.2.4 Bimanual transfer of sequence learning in SRT tasks

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Many skills, like handwriting or speech production, are based on the acquisition and production of sequential regularities. One of the most important behavioral paradigms to study how sequential regularities are learned is the serial reaction time (SRT) task, developed by Nissen and Bullemer (1987). In a typical SRT

task, participants have to react to the location of a series of visual stimuli, by pressing the assigned spatial compatible response keys. When the stimuli are presented following a structured sequence, reaction times (RTs) decrease faster over training as compared to random sequences and suddenly increase when another, mostly random, sequence is introduced. Since all other tasks aspects, besides the sequence, remain the same during this switch, the increase in RT is ascribed to sequence-specific knowledge. One of the key questions is what is precisely being learned during SRT task performance. According to Willingham, Wells, Farrell, and Stemwedel (2000), sequence learning in SRT tasks is represented as a sequence of response locations. By changing the effector sequence independently of the sequence of response locations, they demonstrated that performance deteriorated when the sequence of response locations but not the sequence of effectors changed. We investigated effector-independent learning based on the sequence of response locations by means of bimanual transfer in SRT tasks. Right-handed participants were trained to respond to a probabilistic sequence of spatial stimuli with (four fingers of) the dominant hand. At transfer, half of the participants switched from dominant to nondominant hand, while for the other half the dominant hand was maintained. Within each hand condition, transfer of sequence knowledge was examined with either the originally trained sequence or with a mirrored sequence. This resulted in four conditions with sequences of response locations varying independently of effector sequences. For all four conditions, sequence learning was observed during training. At transfer, sequence knowledge was comparable to the control condition when either the sequence of effectors or response locations changed. However, transfer was absent when both sequences changed. The results indicate that both effector and response location sequences can contribute to sequence learning in SRT tasks. With respect to bimanual transfer, knowledge about the sequence of effectors and response locations transferred perfectly from the dominant to the nondominant hand. Even more, expression of knowledge acquired about the mirrored sequence was only possible when participants switched from the dominant to the nondominant hand, but not when they maintained responding with the dominant hand.

Keywords: sequence learning, bimanual transfer

### 3.2.5 The consolidation of implicit and explicit sequence knowledge in SRT tasks is not influenced by d-amphetamine.

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Consolidation refers to the idea that memory storage doesn't occur instantaneously, but develops gradually after initial learning. Most of the research on consolidation processes has focused on explicit rather then on implicit learning. For

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example, in previous studies with explicit learning, it was demonstrated that d-amphetamine improves long-term retention of words by enhancing consolidation (Soetens et al., 1995; Zeeuws & Soetens, submitted). In recent studies, memory consolidation of motor processes has been examined in the context of sequence learning (Goedert & Willingham, 2002). In the present study we investigated consolidation of movement sequences by means of a serial reaction time (SRT) task. In particular, we examined whether d-amphetamine influenced the consolidation of sequence learning in the same way as in explicit, verbal tasks. In a double blind, placebo-controlled study, participants were administered 10 mg d-amphetamine and placebo orally one hour before learning. The task of the participants was to press a key that directly corresponds to the spatial location of a circle appearing on one of the four lines arranged horizontally on a computer screen. The circles appeared in a repeating sequence of spatial locations. In the implicit condition, participants were unaware of this sequence, whereas in the explicit condition participants were informed about the structure of the sequence. One day and one week after initial learning, participants were again submitted to the SRT task. Comparing interpolated random sequence blocks with adjacent structured blocks assessed sequence learning. The results show sequence learning in the implicit and in the explicit condition for both drug treatments. No differences in sequence learning between d-amphetamine and placebo were found. Moreover, faster reaction times were measured at the beginning of a subsequent session as compared to the last block of the previous session, which indicates that the sequence knowledge has been consolidated between two sessions. No difference between amphetamine and placebo was found on the consolidation process. The results indicate that d-amphetamine has no effect on motor performance in a sequence-learning task. This seems to support the notion that d-amphetamine produces little or no change in motor performance in healthy participants. Importantly we found that consolidation knowledge is at play both in explicit and implicit sequence learning tasks. The evidence for the role of consolidation in sequence learning has important implications for the discussion about separate learning and memory systems; and for the distinction between implicit - explicit and verbal - nonverbal memory tasks.

**Keywords**: sequence learning, consolidation, d-amphetamine, implicit and explicit learning

### 3.2.6 When both mental rotation and visual perception rely on a mentally simulated grasping movement

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When solving a left-right judgment task that requires rotating images of hands, subjects simulate either a positioning (i.e. Parsons, 1994) or a grasping manual

movement (i.e. Olivier et al, 2004). This paper deals with the grasping manual movement subjects mentally simulate when using door-handles in these judgment tasks. Nineteen subjects were asked to judge the laterality of rotated handles drawings presented successively to the right and left visual hemifields by clicking on a mouse using either their right or left hand. The results showed that: 1) the performances varied with the rotation angle at which the stimulus was presented, indicating that the subjects mentally simulated a rotation process; 2) Handles requiring a wrist pronation to be grasped were recognized quicker than handles requiring a wrist supination to be grasped. 3) Right handles were recognized quicker than left handles. This last result was found whatever the rotation angle of the stimulus, and also when the stimuli were presented in their usual orientation. This last finding suggests that not only mental rotation but more generally visual perception relies on the mental simulation of a grasping movement.

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### 3.2.7 Programming of brief isometric force pulses

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According to the Parallel Force Unit Model (PFUM) the programming of an isometric force pulse requires the specification of the number of force units and force unit duration. The programming of a force pulse with minimal time-to-peak force is an exception, however, as force unit duration is limited by the minimal possible value, which should be more easily to adjust than larger force unit durations. Therefore, the duration of the programming process should be shorter for these force pulses and hence should result in shorter RT. Four experiments assessed this prediction using a response precuing procedure. In each experiment the participants produced isometric flexions with their left or right index finger and time-to-peak force was manipulated within a block. The results

are consistent with the predictions of PFUM. The results, however, are at variance with alternative accounts which assume that RT depends primarily on response duration or rate of force production.

### 3.2.8 Influence of walking on time perception

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**Keywords :** Time, Production, Walking, Rhythm.

Piaget (1966) postulated that time perception is generally dependant on movements and velocity of the people. Newman (1972, 1976) realized several experiments, where she asked the subjects to produce 40s durations while walking on a treadmill at various speeds. These first results (Newman, 1972) did not show a significant relation between the speed of walking and the accuracy of the 40s durations produced. However, during the second experiment (Newman, 1976), the results obtained were contradictory and suggested that there could be a direct connection between rhythm of walking and time perception. The purpose of our experiment was to determine whether a variation in the rhythm of walking could influence the perception of time. Six female subjects produced 3s and 7s durations according to 5 different conditions. There was a first condition where subjects were motionless. In the other conditions, subjects had to walk straight during 3s and 7s at various speeds (spontaneous speed, slow speed and fast speed). There was also a condition where subjects had to walk on place. An analysis of variance (ANOVA), on the errors produced ($F_{(4, 250)} = 15.148$, $p < 0.001$), revealed that the condition of walking on place (mean = 0.25; SD = 0.97) and slow speed (mean = 0.39; SD = 1.02), were significantly different from the motionless condition (mean = - 0.23; SD = 0.74). The subjects produced a longer time when their rhythm of walking was low, as in the experiment of Newman (1976). However, there was no difference between the motionless condition and the conditions of walking at spontaneous speed (mean = - 0.62; SD = 1.14) and fast speed (mean = - 0.29; SD = 0.90). It seems that these two conditions require a less significant attention level. Then, the subjects would compensate the felt effect of the rhythm of walking on their time perception. But the results showed that the subjects tended to under-produce time for these two conditions. We therefore suggest that a high rhythm of walking is associated with a fast flow of subjective time, i.e. with an acceleration of the pulses of « internal clock ».

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### 3.2.9     An overview of hypotheses for antidepressant effects of Exercise

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The effect of exercise on depression has been a subject of interest for many years. Many studies demonstrated antidepressant intervention of exercise. They support the belief that exercise has been proven effective in improving depression. By reviewing the relevant published articles, the purpose of this paper is to discuss the possible causality for effect of exercise on depression. The mechanisms mediating the beneficial effects of exercise on mental health are unknown, although several hypotheses have been forwarded. There are many possible explanations to how exercise works to alleviate depression, with some research done on each possible theory. The hypotheses stated so far by scientists are either biological or psychological. Biochemical hypotheses are the regulation of chemicals such as hormones in the body or associated with changes in the nervous system and psychological theories cover the possibility of mental differences caused by exercise. Whatever the reason is for exercise's mood enhancing effects is not necessarily of greatest importance. The base is that engaging in physical activity has very powerful antidepressive effects. There may be a combination of these hypotheses that can explain better the causality of antidepressant effect of exercise.
Key Words: Exercise, Depression, Hypothesis

### 3.2.10 The influence of perception-action coupling in a perceptual training program

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Video-based simulations with varying degrees of instruction and feedback have been used to enhance perceptual skill in sport (Williams & Ward, 2003). The dominant cognitive view in expertise research focuses on the knowledge bases that underlie skilled perception. New theories on action planning emphasize a common representational medium in which perceptual contents and action plans are coded (e.g. Hommel, Müsseler, Aschersleben & Prinz, 2001). The impact of action-related processes on the development of decision-making skills has been studied in perceptual training program. Varied degrees of perception-action coupling were used to develop tactical decision making skill in junior soccer players. N=41 male junior soccer players participated in the experiment (mean age 16.43, SD = 1.01). Video simulations that recreate the attacker's customary view of a typical "three-against two-player" situations where projected onto a white screen (3.23 m x 2.43 m) in front of the subjects. The video-based test and training programs required the participant to make tactically correct decisions as fast as possible. The participants were split into three groups. During the training sessions (3 x 70 video clips) the subjects of the perception-action coupling group (PAC) had to kick a ball to one of three boxes. The subject of the perception group (PG) had press one of three buttons. The control group did not receive any training between pre-, post- and retention-test. The test was based on 51 video clips in which the participants had to kick a ball to one of three boxes. Results showed that the perception-action coupling group and the perception group improved their reaction times, $F(2, 22) = 5.51$, $p < .05$, partial $\eta^2 = .33$. In contrast, no improvement could be found for the control group. Additionally, no interaction could be found between the perception-action coupling group and the perception group over the three measuring points, $F(2, 54) = 0.77$, $p = .43$. The results show that the perception-action coupling group did not show a more significant improvement in performance in tactical decision making skills than the perception group (see also Williams, Ward, Smeeton & Allen, 2004). It appears that tactical decision making skills can be improved through perceptual training programs regardless of whether the learner has to respond physically to the action (kicking) or merely gives a perceptual judgement via pressing a button.

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## 3.3 Biomechanics/Robotics

### 3.3.1 A kinematic investigation of early walking aids for transtibial amputees: A case study

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Early walking aids (EWAs) are commonly prescribed to lower-limb amputees to begin walking as early as five days following amputation (Lein, 1992). The early use of an EWA helps reduce oedema in the stump (Reith & Arneja, 1992) and incorporates early gait and balance retraining during the rehabilitation process. The purpose of this investigation was to compare the kinematic characteristics of a lower-limb amputee when walking with an articulated and non-articulated EWA. One healthy, transtibial male amputee (age: 46 years; height: 165 cm; mass 91 kg), with 2 months' prosthetic experience, participated in this study. For the control condition, the participant completed several walking trials with his daily prosthesis (Endolite system with MultiFlexAnkle). The participant then walked up and down a walkway in two experimental conditions; first, when fitted with a Pneumatic Post Amputation Mobility articulated EWA and secondly, with the Amputee Mobility non-articulated EWA. Adequate rest time was given between conditions. Two-dimensional kinematic data were captured in the sagittal plane at 50Hz. Dependent variables included walking speed, step length and stance duration. The participant was able to walk successfully with the use of parallel bars wearing both types of EWAs. Mean walking speed in the control condition was 0.72 ($\pm$0.04) m·s$^{-1}$. In the experimental conditions, walking speed was reduced by half with both the articulated and non-articulated EWA to 0.36 ($\pm$0.01) m·s$^{-1}$ and 0.34 ($\pm$0.03) m·s$^{-1}$, respectively. In the control condition, prosthetic and intact step lengths were quite similar (Figure 1). However, when walking with an EWA, step length on both limbs decreased. Compared to the control condition, a decline of 36% in intact step length occurred

with a non-articulated EWA. The noticeable decrease in walking speed was attributed to shortened step lengths of both limbs. Intact and prosthetic stance duration was very similar in the control condition (Figure 2). In both experimental conditions, intact stance duration increased. The most notable difference in prosthetic stance duration occurred with the non-articulated EWA, which decreased by 22% from the control condition to 58 (±2) %. Reduced prosthetic stance, compared to the intact limb, has frequently been reported in the literature as a compensatory action for increasing gait stability (Donker & Beek, 2002). In this study, it was believed that the participant was more confident weight-bearing on the articulated EWA compared to the non-articulated EWA. Future studies will investigate the long-term benefits of using an articulated EWA by examining kinematic and neuromuscular gait adaptations.
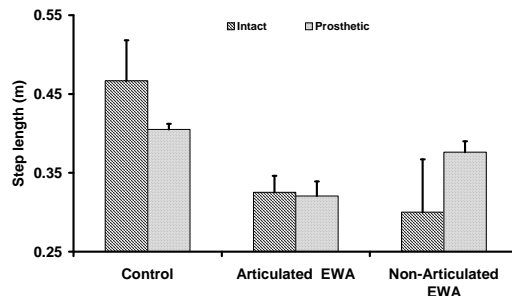


Figure 1. Intact and prosthetic step length
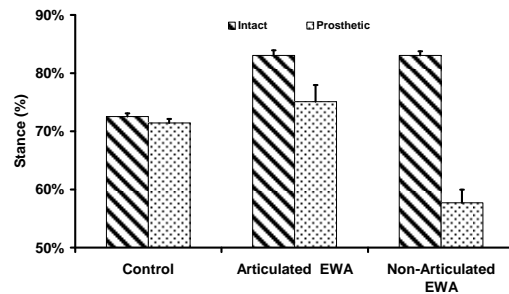


Figure 2. Intact and prosthetic stance duration

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### 3.3.2 Influence of lining insoles on reducing local pressures on feet

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KEY WORDS : lining insole, local pressure, Pedar mobile, stepping forces INTRODUCTION : The human foot evolved to walk on soil and grass rather than on hard concrete and other surfaces people step onto every day.Hardened surfaces are not able to damp. The loss of damping abilities of these surfaces is replaced so by the absorbing ability of footwear bottom parts. Recently, there has been growing interest in using lining insoles which are able to damp the stepping forces. There are only few studies concerning an optimum solution of lining insoles.[1,2,3] METHODS : The  insoles have been tested in a single-purpose all-rubber work boot. Just this type of footwear demands the necessary comfort and good health promoting properties.Two types of all-rubber boots have been chosen and 8 types of lining insoles. The boots have been tested in total by 25 probands. This measuring has been carried out in laboratory conditions.For measuring the treading forces, the Pedar mobil (Novel Munich) has been used. The values of the pressures recorded have been evaluated using the firm´s Pedar Winn software. RESULTS : The impacts and the shocks are mostly damped and the pressures when walking are reduced when using a special shaped sock lining, latex-foam insoles with upper layer of cotton and lower layer of artificial cork and the gel insoles. Furthermore, slight damping properties have been found with sock linings covered with aluminium and with insoles made of another latex foam. Other sock linings prove similar or slightly worse properties than the original lining insole. CONCLUSION :In virtue of the above results, it is possible to make a recommendation to provide the work boots with insoles which promote the right body posture, protect the articular system, damp the impacts and undesirable vibrations in avoiding so the occurrence of accidents or feet deformations. Because the work boot are designed for being worn in a difficult terrain which is demanding from the point of view of physical demand concerning the musculature of the foot and of the whole kinetic system thereof.

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### 3.3.3 Influence of obesity reduction by physical activity and caloric restriction in children on plantar foot pressure changes

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Key words: children obesity, plantar foot pressure, Pedar system, body mass index

Introduction: Obesity is a risk factor for range chronic diseases of adult life and some directly affected children themselves as diabetes mellistus and hypertension. Obese children also have overloaded locomotion system, artodynia and orthopedical problems. Till this time was not give attention to questions of overloaded foot skeleton in children with higher BMI. For this reason was suggested this study to confirm whether weight changes for obese children during active movement could be projected on the distribution of force between the foot and the footwear insole. Methods: Along of five-week weight loss courses for 39 children and adolescents (24 girls, 15 boys) in the age of 10 to 19 years, dynamic pressures were measured between the foot and footwear insoles using a Pedar instrument. The results were evaluated with NovelWin software, which enables the establishment of maximum pressures at defined locations, the course of maximum force and centres of gravity. The measurement was conducted at the beginning of the course and after its completion. Results: The average value of weight loss achieved $3.31 \pm 1.85$ kg ($3.22 \pm 1.74$ kg for girls and $3.51 \pm 2.18$ kg for boys). From the extensive set of measured data, changes were analysed in values of maximum pressures in the frontal, arch and heel sections on the surface of the foot at the beginning of the experiment and at the end in dependence on the differences in the weight in all of subjects and also separately at boys and in girls. Increasing trend of the difference in maximum pressures in positive changes in the weight in all of subjects and also in boys and girls was found especially in the frontal part of the foot. In the arch area of the foot there were not probed significant changes in maximum pressures and in the heel area there is the distribution of plantar foot pressure mostly affected by the biomechanics of walking.Conclusions: During active movement, weight loss in children in the range from 2-6 kg is significantly projected on the distribution of pressures on the foot, primarily in a decrease in the greatest local pressures.

### 3.3.4 Analysis of impact of prophylactic footwear on diabetic feet during long-time wearing

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INTRODUCTION: The issue of diabetics footwear wearing has been systematically explored only in the last decade. The most important assertion was found, that the lesion (injury) on a diabetic's foot is related to wearing unsuitable shoes. In The Czech Republic the prophylactic footwear is offered to diabetics with the diabetic foot syndrome. This footwear is partly paid by insurance companies. The goal of this research was to study influence of prophylactic footwear on diabetics feet during six months. In this experiment 19 diabetics were monitored. We found out that prophylactic footwear has very efficient impact on diabetic feet and also assist as very effective prevention. METHODS: The research included 19 diabetics (8 men and 11 women) in average age 62,74. Diabetics wore their prophylactic footwear Medi mainly during 6 months (from June to December). The foot proportion was determined and based on characterictics measured [ball point, metatarsus, heel girths in loaded and unloaded conditions; hallux, metatarsus height, foot length, body weight (kg), height (cm)]. The  plantogram was made of which Chippaux-Šmiřák index was assessed. The evaluation of obesity was completed by BMI index. Dynamic pressures were measured between the foot and footwear insole using  the Pedar system. All initiate characteristics were detected at the  beginning and at  the end of the research. RESULTS: In this study we found out that approximately a half of probands are effected by the II. level of obesity. There is 94 % of diabetics who have their feet wider than average footwear wideness. About one third of diabetics have flat feet. There are very interesting relations between figures of BMI and maximum measured pressure. The most occurrence of plantar peak pressure was under the first metatarsus, then under heel and transverse arch. During a half year walking in prophylactic footwear there was no origin of  pressure sores, blisters or ulcers on diabetics feet.  CONCLUSION: There is no enough sufficient attention engaged to diabetics footwear habits. The footwear impacts evaluation of foot complications both positively and negatively. Because of this it is very important to produce, distribute and offer prophylactic footwear in the same way as drugs – clinical tests, measurement parameter or material determination.

### 3.3.5 The Effects of Anatomical Landmark Choice on the 3 Dimensional Loading of the Knee Joint.

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The determination of the centre of rotation of a joint is essential for the accurate calculation of joint kinetics. In a clinical setting the centre of rotation is generally determined by the placement of markers on palpable anatomical landmarks representative of the segment end points (Cappozzo *et al,* 1995). Traditionally the segment end point chosen to represent the knee has been the femoral end point; however with this approach the tibial end point is neglected. The resultant moment arm calculations in the sagittal plane are subsequently affected due tot the artificial lengthening of the tibia. The implications of this effect on the resultant moment the sagittal plane are well documented (Holden & Stanhope, 1998). If the effects of landmark identification are to be further investigated a 3 dimensional picture must be complied taking in to account the transverse and coronal plane activity. The following work set out to investigate how the use of different anatomical landmarks can affect the resultant 3 dimensional loading of the knee. Motion analysis equipment (Qualisys Medical AB, Gothenburg, Sweden) and a force platform (Kistler Instrumente AG, Switzerland) were used for the data collection process with Visual 3D (C – Motion Inc, USA) used for the data processing. To define the centre of rotation of the knee joint two calibration files were collected with the participant in the anatomical position. The medial and lateral femoral epicondyles (Cappozzo *et al,* 1995) and the ridges of the tibial plateau (Field, 2001) were used in defining the knee joint line. Initial results indicate that a difference is found in all 3 planes when the centre of rotation differed through landmark definition. Maximum flexor moment was found to differ by 0.05 Nm.kg, maximum adductor moment differed by -0.02 Nm.kg and maximum torsional moment differed by -0.01 Nm.kg. All difference are based on the femoral epicondyle model being the base measurement with a change representative of the effect caused by the tibial model. This indicates that the different geometry of the tibial plateau and the femoral epicondyles has an effect on the 3 Dimensional theoretical loading of the knee.

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### 3.3.6 Analysis of surface electromyographic activity of selected hip muscles during normal walking in transfemoral amputees with osseointegrated prostheses

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Transfemoral amputation involves considerable disruption to the muscles of the lower limb with consequent profound effects on gait. In subjects who have been fitted with an osseointegrated prosthesis (OIP) muscle surgery is still more radical with no firm fixture of muscles by myoplasty or myodesis. The aim of this study is to investigate activity of selected muscles of the hip joint in OIP amputees in order to determine both individual activity and patterns of activity of muscles during the gait cycle. A clear pattern of muscle activity as measured by surface electromyography (SEMG) would raise the possibility of SEMG being used as a natural sensor for control of an intelligent knee prosthesis. Four transfemoral amputees took part in the study. All were fitted with an OIP and were confident in walking unaided with the prosthesis. Surface electrodes were attached to skin overlying adductor magnus, rectus femoris, biceps femoris, gluteus medius and gluteus maximus. The ground electrode was placed on the wrist. The sampling frequency was 1000 Hz. The subjects were asked to walk along a dual force walkway 3.3m in length. They were requested to repeat the walk 10 times thus providing a minimum of 20 strides for each side. Synchronisation of the data was by means of a contact switch. The SEMG Data was divided into stance and swing phases. The raw data was processed to obtain the root mean square (RMS) values and mean frequencies (MF) by application of the short time Fourier transform(STFT). The adaptive Choi-Williams transform (ACWT) and wave transform(WT) were additionally applied to the raw data. These two transforms are particularly appropriate for analysing noisy stochastic non-stationary signals. The algorithms were written in Matlab ®. Considerable intra and inter subject variance were found for all parameters for all muscles. This has been reported in previous studies both for intact subjects and amputees. However the variance was smaller for the ACWT parameters and the WT parameters than for the STFT and RMS parameters. Patterns of SEMG activity could be discerned during the gait cycle which were however different to that found in intact subjects. From this study one can conclude that amputees develop their own unique control strategy for organising walking following gross disturbance to the lower limb musculature. One can hypothesize that these patterns are mediated by a readjusted central pattern generator that has adapted to the altered proprioceptive input.

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### 3.3.7 Development of non-invasive cluster markers to assess three-dimensional kinematics of the proximal interphalangeal joint of the horse.

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http://www.uclan.ac.uk/other/registry/research/documents/conduct.doc.

**Keywords:** kinematics, equine, horse, cluster markers.

Techniques for collecting equine in vivo kinematic data are extensive, but models of the distal forelimb have often assumed the proximal interphalangeal joint (PIPJ) to be a rigid link. However, mobility of the PIPJ has been documented and more recently two methods developed by Chateau et al. (2004) and Johnston et al. (2004) have emerged to measure three dimensional (3D) rotations of this joint in vivo. Despite these advances, a need exists to develop a robust, non-invasive method capable of describing the movement in six degrees of freedom. Cluster markers have been evaluated for human movement by a number of authors including Manal et al. (2000), who found that a marker set of four markers attached to a rigid shell was optimal. Consequently, the aim of this study was to develop a cluster marker set for the lower limb to assess the three dimensional kinematics of the PIPJ. Five infra-red cameras (ProReflex®, Qualysis Medical AB, Goteburg, Sweden) were positioned on a concrete walkway in a frontal-

sagittal arc and calibrated. Four segments were defined: hoof (PIII), short pastern (PII), long pastern (PI) and metacarpus (MPIII). Rigid clusters with four retro-reflective markers were placed on each body segment. A static trial was recorded with additional anatomical markers on the medial and lateral joint lines. These anatomical markers were removed and kinematic data were then recorded at 240 Hz during the walks using the rigid clusters. Data from four ponies were collected. The completed successful trials were then digitised using QTM (Qualysis Medical AB, Goteburg, Sweden) and exported as a C3D file to Visual 3D (C-Motion Inc., Gaithersburg, USA). The kinematic data was then smoothed with a Butterworth 4th order filter with a cut off frequency of 10 Hz. For each subject an ensemble average was computed from five replicates of the walks. Joint kinematics were calculated using the Calibrated Anatomical System Technique (CAST), Cappozzo et al. (1995), allowing a complete kinematic description of motion of the lower limb to be obtained.

Notable movement in all three planes occurs at the metacarpophalangeal (MPJ), PIPJ and distal interphalangeal (DIPJ) joints, which suggests that all three joints appear to have a functional role in all three planes. Typical movement patterns for the PIPJ included; lateromotion (displacement of the distal segment in the lateral direction) and lateral (external) rotation of the short pastern about the long pastern, during landing extension, followed by flexion, which reached a maximum after hoof stabilization in agreement with Chateau et al. (2004), and then medial (internal) rotation and slight mediomotion (displacement of the distal segment in the medial direction). Maximum extension together with lateral (external) rotation was found during the propulsion phase, which was followed by several degrees of lateromotion during breakover.

These results demonstrate that using camera based movement analysis with surface placed rigid clusters and the CAST technique detailed three dimensional movement of the equine lower limb may be quantified non-invasively, which may be useful for future clinical analysis where invasive techniques are not appropriate.

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### 3.3.8 Concerning the nature of slow component in postural sway

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The current study analyses the low frequency (less than 0.1Hz) component of human body motion during the vertical posture stabilization. The analysis is based on the results of the experiments by Gurfinkel and co-workers, which were published in [1]. The experiments have shown that: (i) if the support inclines sinusoidally with 1.5 degree amplitude and 160 seconds period then deviation of the human body from the vertical is also sinusoidal with the same period, but it lags 120-140 seconds behind the support inclination. (ii) if the support inclines with an angular velocity 0.05 degree per second during 20 seconds then the human body deviate from the vertical in the same direction as the support; the start and the end of the support inclination evoke exponential transient with characteristic time value about 10 seconds. It is also assumed in [1] that proprioceptive information is the only one available in the experiment. The current study proposes a mathematical model of human vertical posture stabilization that describes the results of the experiments from [1]. Inverted pendulum model is used for the human body; the equilibrium point hypothesis (lambda model) [2] is used for the ankle torque. Besides, it is assumed that there is a level of posture control that is aimed to estimate the vertical from the proprioceptive information only and that this level assigns lambda parameter for ankle joint. This level is modelled using methods of adaptive control. Thus, the stabilizing torque is proportional to the deviation of the ankle angle from the estimated vertical. One can say that the estimated vertical provides a 'reference frame' for the stabilization process. As human body oscillations are usually subthreshold for the vestibular apparatus, the posture control system uses proprioceptive information to estimate the vertical. The estimation process is imperfect and it has characteristic time value about 10 seconds. Thus, according to the proposed model low frequency component of postural sway reflects uncertainty of the posture control system in its knowledge about the vertical.

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### 3.3.9 Planning of Movements in Human and Robotic Soccer Players

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Introduction: The domain of our research and development is the RoboCup [1] Small Size League for robot soccer. The research is done as part of the Vienna Cubes project [2] which participates in the F180 league [3]. In this league each team consists of five autonomous robots, which compete in a soccer match. The Artificial Intelligence (AI) is made up of four hierarchical layers of functionality: the Multi-Agent Planning System (MAPS) layer, the Motion Generation layer, the communication layer and the robot control layer. Additionally some unlayerd cross-linked components representing centres of specialization like the visual cortex and the system for motion estimation and prediction are implemented.

Overview: In this presentation we compare the process of motion planning in a soccer match in human players to that in the Vienna Cubes AI. Motion Planning in Human Soccer Players and in a distributed AI. Recent advances in neuro-physiology reveal a very complex mechanism in how humans plan any kind of action. The complete sensory input of around $10^9$ bit/s is constantly processed and compressed to a dataflow of around $10^2$ bit/s which is present in the conscious mind. This relatively small amount of highly structured and relevant information is used in the many planning processes of human soccer players essential for the game. However, around $10^7$ bit/s of information output is permanently visible in body movements and control of all the inner processes to keep a human alive. This means, that 1 "conscious" bit/s triggers the huge output of $10^5$ bit/s. The $10^2$ bit/s, present in consciousness, are carefully selected and include options of possible movements and a complex mechanism of prepared reflexes which can be used or suppressed. Further reactions exist, that can only be slightly controlled by the conscious mind, e.g. closing the eyes if in danger, is to be avoided.

In our robots the system is a far less complex, however the similarities of the AI to the human process are overwhelming. When implementing a distributed AI for a multi-agent system in a complex, highly dynamic environment, data propagation and interpretation between functional layers and centres of specialization becomes a critical factor. Data has to be available not only consistently but in time to minimize the gap between the observed environment and its representation within the AI. A dynamic mechanism allowing component independent propagation, interpretation and reduction of received information becomes mandatory, to suppress or enforce, modify or transform internal data.

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## 3.4   Dynamical Systems

### 3.4.1   Emergence of collective patterns in spontaneous displacements of badminton players

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Research on dynamical pattern formation (Haken, 1977; Kelso, 1995) showed that various human behavioural patterns followed the same underlying principles of self-organization as numerous other biological systems, ranging from firing neurons to applauding audience (Strogatz, 2003). Surprisingly, studies on inter-individual coordination are seldom and have been mostly restricted to laboratory situations (Schmidt, 1990). In the present paper, we investigated inter-individual coordination in a more "natural" environment and analysed spontaneous synchronisation of the players' displacement in badminton. Their unceasing to-and-fro displacements about a "home" reference position, located in the middle of each semi-court, are akin to those of an oscillator, and the reciprocal attending of both players establishes an informational coupling. Thus, theoretically, the displacement of the two players can be analysed as a system formed by two non-linear coupled oscillators. Therefore, we assume that the relative phase between their displacements is a pertinent collective variable to characterize the various modes of synchronization exhibited by the players along the game. A camera set vertically over the court videotaped two pairs of badminton players ranked at the national level. In a first condition, called "co-operation", players were instructed to realize long trials, whereas in a second condition, called "competition", they were instructed to play a match in which one player is an attacker and the other a defender. In each condition, forty trials with an average duration of 40 s were analysed. The players' displacements were decomposed according to their Cartesian coordinates. For all trials, the continuous relative phase of lateral and backward-forward displacements was computed using a Hilbert algorithm. Results showed that in the cooperation condition, two modes of synchronization close to a relative phase value of 0°

(in-phase) and 200° (anti-phase) were spontaneously realised by the players, in-phase more frequently than anti-phase, defining the attractors of the underlying dynamics of the system. In the competition condition, only the in-phase mode was spontaneously realised in both the lateral and backward-forward directions. The annihilation of the anti-phase mode, intrinsically less stable, with an increasing level of constraint is a process typical of adaptation in self-organised systems. In conclusion, this research showed that in line with previous work on tennis (Palut and Zanone, in press), the apparent complexity in the displacements of dual sports players can nevertheless be described more simply at a macroscopic level by the dynamics of two weakly-coupled non-linear oscillators. Such a description opens new avenues to investigate the complex relations between the individual and the collective behaviour in humans, when they pursue either a common or a different goal, still a puzzling topic in biological and social sciences (Vallacher and Nowak, 1993; Strogatz, 2003).

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### 3.4.2 A dynamical approach to learning: pre-learning dynamics determines the transfer of new coordination patterns

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Bimanual coordination may be governed either by bistable dynamics characterized by two stable attractive patterns at 0° and 180° of relative phase or by tristable dynamics exhibiting a third attractor about 90°. This pre-existing organization interacts with learning a new pattern. In particular, for bistable systems, acquiring a new pattern of 90° entails an automatic stabilization of the pattern at −90°, never practiced, a clear sign of transfer based on symmetry (Zanone &

Kelso, 1997). We hypothesized that a positive transfer should occur from 45° to 135°, and inversely, and that the learning and retention processes should be different for bistable and tristable dynamics, because of the distance between the to-be-learnt and pre-existing patterns (Zanone & Kostrubiec, 2004). Participants with bistable and tristable dynamics had to synchronize hand movements with a visual metronome in order to learn two different patterns successively. Half practiced first 45° then 135° (45→135), and vice-versa (135→45) for the other half. Two practice sessions, separated by 24 hours, were followed by 4 recall tests (immediate, differed, 24 hours, and one week later). Results indicate that a) 45° showed stronger signs of learning than 135°; b) learning in the 135→45 order was easier than conversely; c) for bistable dynamics, the first-learnt pattern was slowly forgotten, whereas the other pattern was retained; d) for tristable dynamics, 45° and 135° shifted immediately toward intermediate values. Practicing a (hard) 135° pattern before an (easy) 45° pattern leads to a better learning than vice-versa, suggesting asymmetric transfer. Regarding bistable dynamics, their rigidity renders learning order-dependent, and a slow retroactive interference operates over time. For tristable dynamics, learning involves transient adaptation only, that is, no persistent reorganization of their dynamics.

Keywords: dynamical approach, transfer of learning, coordination patterns.

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### 3.4.3 Recruitment of degrees of freedom in synchronization-syncopation tasks

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Dynamics of perception-action patterns has been extensively studied in tasks involving flexion-extension movements of the index finger [1]. In this task, the system answers to the loss of stability by reordering the same biomechanical degrees of freedom (dfs) at a critical value of oscillation frequency. However, in abduction-adduction perception-action tasks realized on the horizontal plane of motion, the system can recruit the vertical plane. Recently, we showed that recruitment of the vertical plane was influenced by the informational context of the task. Indeed, in a first experiment [2], we modified the stability on the hori-

zontal plane by providing a haptic contact either in coincidence or counterphase with the metronome. Results showed that any change in stability on the horizontal dimension led to a change of recruitment of the vertical plane. Moreover, the abduction-on-the-beat pattern was more stable on the horizontal dimension and produced simultaneously more recruitment than the adduction-on-the-beat pattern. If the recruitment was prevented by physically constraining the displacement of the finger to the horizontal plane, the more stable abduction-on-the-beat pattern was destabilized [3]. Thus, we concluded that the recruitment of the vertical plane increased the stability of the abduction-on-the-beat pattern. Taking together, our results revealed a trade-off between the stability of perception-action pattern on the horizontal plane and the recruitment of the vertical plane. The remaining question is to know if this trade-off persists when the (in)stability is related to abstract, strategically-defined constraints as represented by the coordination strategy. This issue was addressed in the present study. Subjects had to synchronize either peak abduction or peak adduction of the right index finger with an auditory metronome. These patterns of coordination were realized either in synchronization or in syncopation with the auditory metronome. We measured the relative phase and its variability, the number of transitions and the magnitude of recruitment of the vertical dimension. Results showed that for both abduction and adduction patterns, the synchronized mode was more stable than the syncopated mode. Moreover, for both coordination modes, abduction patterns were more stable and recruited more than adduction patterns. On the contrary, the recruitment of the vertical plane of motion was not affected by coordination modes. These results show that recruitment of dfs is related to pattern stability and may be functional to maintain the required coordination pattern. Moreover, they strongly suggest that the occurrence of recruitment predominantly depends on the (in)stability caused by the neuromuscular constraints.

Keywords: Coordination dynamics, Self-organization, Recruitment of degrees of freedom, perception-action pattern, synchronization and syncopation.

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### 3.4.4 Plane of motion: A symmetry-breaking parameter that mediates the coalition of constraints

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In the present study, we hypothesized that the modulation of coordinative stability and accuracy due to the coalition of egocentric (neuro-muscular) and allocentric (directional) constraints vary depending on the plane of motion in which coordination patterns are performed. Participants were requested to produce rhythmic bimanual movements of the hands in the sagittal plane (i.e. up and down oscillations resulting from flexion-extension of their wrists). The direction of movements (isodirectional/non-isodirectional), timing of activation of muscle groups (homologous/non-homologous), visual feedback (vision/no vision) and across-trial movement frequency (1.0, 1.5, 2.0, 2.5 and 3.0 Hz) were manipulated. In the transverse plane of motion, the egocentric constraint is often considered as the one predominantly determining bimanual coordination stability, whereas the allocentric constraint proves to dominate in the sagittal plane (e.g. Swinnen, 2002). Our results reveal that both the egocentric and the allocentric constraints modulate pattern stability and accuracy in the sagittal plane of motion. However, the allocentric constraint was found to play a dominant role over the egocentric one when bimanual coordination was performed in such context. Interestingly, removing vision of the moving limbs only slightly destabilized movements regardless of the effects of directional and (neuro)muscular constraints. Our results shed new light on how egocentric and allocentric constraints interplay for bimanual coordination in the sagittal plane of motion by extending previous findings on hand-foot coordination (e.g. Salesse & Temprado, 2005; Salesse et al., 2005). Here the dominance of the allocentric constraint markedly differs from the overwhelming role of (neuro)muscular constraints widely reported in the transverse plane of motion (e.g. Temprado at al., 2003). Thus, not only do our results argue for considering the emergence of coordination patterns as the result of a coalition of multiple constraints but they strongly suggest that the plane of motion is a key factor that mediates this coalition and its effects on bimanual coordination. Recent accounts on coordination dynamics have suggested that the spatial orientation between limb movements may act as a (symmetry-breaking) parameter allowing other constraints to emerge as dominant factors in modulating bimanual coordinative stability (Fuchs & Jirsa, 2000). Our study suggests that the plane of motion in which coordination is executed has a comparable effect.

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### 3.4.5 Dissociation versus Coalition: A study of the role of egocentric and allocentric constraints in handheld-pendulum coordination

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It is widely accepted that the coordination of movement is founded upon a coalition of constraints of various origins (e.g., Salesse, Temprado, & Swinnen, 2005; Temprado et al., 2003). However, in a recent study using handheld pendulums, Park et al.'s (2001) suggested that egocentric (muscular) and allocentric (directional) constraint affect separate aspects of coordination dynamics, that is respectively pattern stability and pattern accuracy. In the present experiment, we contend that Park et al.'s findings resulted from comparing bimanual movements performed in the sagittal and the paracoronal planes of movements. Indeed, previous studies have shown that the plane of motion mediates the coalition of constraints on bimanual coordination (Temprado et al., 2003; Salesse, Oullier & Temprado, 2005). Thus, in the present experiment, we investigated the effects of egocentric (muscular) and allocentric (directional) constraints on bimanual performance for coordination patterns performed in the sagittal planes of motion only. Participants were requested to produce rhythmic bimanual oscillations of a pair of pendulums in the parasagittal planes (i.e. adduction and abduction of their wrists). The direction of movement (isodirectional/non-isodirectional), timing of activation of muscle groups (homologous/non-homologous), movement frequency (from 0.73 Hz to 1.72 Hz by steps of 0.07 Hz), and detuning between the two pendulums (0 or 1.7 $rad.s^{-1}$) were manipulated. Mean relative phase, variability of relative phase and the number of phase transition were analyzed. Results show that, whatever the timing of activation of muscle groups, movements performed in opposite directions were less stable than movements performed in the same direction. Moreover, patterns of coordination in which homologous muscles were activated simultaneously were more stable than those in which non-homologous muscle groups were coactivated.

The same results were observed for pattern accuracy. These results are not consistent with Park et al.'s suggestion of dissociated influence of egocentric and allocentric constraints on bimanual stability and accuracy, respectively. Rather, they suggest that bimanual coordination is founded upon a coalition of constraints, each of which may contribute to both pattern stability and accuracy. These results extend previous findings on the role of the plane of motion in the coalition of constraints that shape coordination dynamics (e.g. Salesse & Temprado, 2005; Salesse, Temprado, et al., 2005). As such, the present study increases our understanding of the principles governing perception-action coupling in the production of coordinated movements, and brings new insight into the current debates on movement sciences (Temprado & Salesse, 2004).

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### 3.4.6 Does plane of motion mediate the learning and transfer of relative phase in bimanual coordination?

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To date both the effects of egocentric (muscular) and allocentric (directional) constraints on bimanual rhythmic movement have been associated with execution of this coordination in different planes of motion. In recent studies, we have shown that the allocentric constraint is dominant in the sagittal plane of motion in both learning (Temprado & Swinnen, 2005) and execution (Salesse, Oullier & Temprado, 2005) of bimanual coordination. The question therefore remains regarding in the transverse plane of motion. The present study addresses the issue of how the allocentric constraint contributes to bimanual pattern stability

using a well-established learning and transfer paradigm. Participants were required to learn rhythmic bimanual movements of 45° of muscular relative phase in the transverse plane of motion at 1 Hz (i.e. right and left oscillations resulting from flexion-extension of their wrists). This learned pattern corresponded to 135° of spatial relative phase with respect to the external reference frame (i.e., predominantly in opposite directions). Participants performed 4 sessions of 50 trials over 4 days. A pre-test, two post-test (after 100 and 200 trials) and a retention test (2 days after the end of the acquisition) were carried out in both the transverse and the sagittal plane of motion (i.e. up and down oscillations resulting from flexion-extension of their wrists). These tests consisted of 0°, 45°, 90°, 135° and 180° patterns of muscular relative phase. In the sagittal plane of motion, spatial relative phase was manipulated by changing forearm posture (both hands in prone position or one hand in prone and the other in supine). Since the allocentric constraint proved to dominate in the sagittal plane (Salesse, Temprado & Oullier, 2005), a transfer of learning from the transverse to the sagittal plane of motion permitted to determine whether direction of motion does matter in the transverse plane. More specifically, a positive transfer would suggest that directional coding of movement is similar in both the transverse and the sagittal planes of motion. Expected results were: muscular relative phase should transfer from the transverse to the sagittal plane of motion; 2) spatial (directional) relative phase should not transfer from the transverse to the sagittal plane of motion. Such a result would confirm that spatial constraints are subordinate constraints in the transverse plane. However, the possibility exist that neural coding of movement direction in the transverse and the sagittal plane differ with respect to the reference frame in which it occurs (i.e., with respect to body midline or to extrinsic frame of reference).

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### 3.4.7 Does the constant practice or the variable practice has more effect on the skill acquisition of a quick, discrete aiming task both transfer and delay test

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The specificity of learning hypothesis derives from the motor program theory proposes that motor skills are specific and only superficially resemble other

similar skills or variations of the same skill. In other words humans have to initiate different motor programs to perform different movement pattern. On the other hand, the variability of practice hypothesis derived from schema theory proposes that practicing of a task variations are essential to the development of schema responsible for movement pattern production and movement pattern learning. This paper contrasts these two positions aimed at determining the influence of variable or specific acquisition practice of a quick, discrete aiming task. 8 undergraduate sport students from University of Münster participated in the experiment. The subjects were asked to make a quick extention-flexion in their elbow joint using their palm to generate a vacuum to blow out a candle without any direct contact with the flame. They were naive to the purpose of the study. The successful percentage of the subjects is used to detect the influence of the learning process both constant and variable practice group, because this parameter reflects the instruction given to the subjects that is, subjects were instructed to blow out the candle. One hand comparing the transfer of the variable learning group and the main effect of the constant learning group, we can conclude that the prediction of the specificity of learning principle: "that acquisition with criterion task variations do not enhance post and retention test performance on the criterion task. Only the specific practice adds to the criterion task to the post and retention performance" (Barnett, Ross, Schmidt, & Todd, 1973) found not to be true. On the other hand the prediction of schema notion "that the variable practice facilitates transfer to a novel task - found to be true -, but does not directly address the influence on a task variation that has been practiced" (Shea, 1990) found not to be true.

Key words: variability, schema theory, specificity, skill acquisition, dynamic system

### 3.4.8    Imagining syncopated and synchronized rhythms: A functional MRI study

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The relative contribution of motor and perceptual processes in mediating behavioral stability is a topic of ongoing discussion in the literature on coordination dynamics. Such debate has proceeded largely independent of what is going on in the brain. Recent studies have demonstrated differences in neural activity when participants make synchronized (flex on-the-beat) or syncopated (flex off-the-beat) movements in time with an auditory metronome (Kelso et al, 1998). Syn-

copation typically results in additional activity within supplementary motor area, premotor cortex, subcortical areas and cerebellum (e.g. Jantzen et al., 2004). The functional nature of the aggregate of neural structures defining this broadly distributed network suggests that both perceptual (i.e. sensory integration, timing and preparation) and motor (i.e. motor output and resulting feedback) are involved.  In the present study, using BOLD measures of neural activation (fMRI 1.5T), physically executed and imagined rhythmic coordination are compared in order to better assess the relative contribution of hypothesized neuro-musculoskeletal mechanisms in modulating behavioral stability. The executed tasks were to coordinate index finger-to-thumb opposition movements of the right hand with an auditory metronome (pacing at the constant frequency of 1.25Hz) in either a synchronized or syncopated fashion. Imagination involved the same tasks, except without physical movement. Thus, the sensory stimulus and coordination constraints were the same in both physical and imagination tasks, but the motoric requirements were not. Results clearly reveal that neural differences between executed synchronization and syncopation found in premotor cortex, SMA, basal ganglia and lateral cerebellum persist even when the coordinative patterns were only imagined. Neural indices reflecting behavioral stability were therefore not abolished by the absence of overt movement. In addition, activity in the primary auditory cortex (superior temporal gyrus) was modulated by both the presence of movement and the nature of the coordination. The present study sheds new light on the "perceptual versus motor debate" in coordination dynamics by demonstrating that differences in brain activation persist between synchronization and syncopation even when the coordination pattern is imagined and movement is not executed. Thus coordination phenomena are not exclusively rooted in "purely motoric" constraints. In addition, activity in the auditory cortex, a so-called sensory brain area, is modulated by movement, attesting to the intimacy between perceptual and motoric processes in coordination dynamics (Oullier et al., 2005).

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### 3.4.9 Between-people coordination in virtual environments is modulated by the structure and the richness of the visual background.

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The nature and the richness of visual information provided by the environment in which tasks are performed can alter movement perception, accuracy and variability (e.g. Blakemore & Snowden, 2000). The effects of such environmental/informational manipulations have essentially been tested on reaching, tracking and grasping tasks (e.g. de Grave et al., 2004). However, it is well established that rhythmic coordination dynamics is informational in nature (Kelso, 1994). For instance, recent studies on interpersonal coordination (when the two limbs to coordinate are only coupled by vision) revealed that vision of someone else's actions can influence the way we perform the same movement (e.g. Schmidt & O'Brien, 1997; Temprado & Laurent, 2004) or even induce spontaneous interpersonal synchronization (Oullier et al., submitted). To date, little remains known regarding how the structure and the richness of the visual settings could influence rhythmic coordination patterns. In the present study, pairs of participants were asked to perform rhythmic interpersonal coordination while the structure of the visual environment was manipulated. We hypothesize that, when a dyad is asked to intentionally perform specific phase relations (0° and 180°), the stability of its coordination can be modulated by changing the structure and the richness of the visual environment. Each participant was asked to oscillate a manipulandum with his/her right hand. Both participants wore restricting goggles while looking at a big screen so that the only thing they could see was a pair of dots moving up and down. The movement of each dot represented the oscillations of their respective manipulandum. Depending on the experimental conditions, the dots were standing out against different fixed backgrounds (e.g. grid, perspective and visual illusions). Results reveal that the nature of the visual background can alter significantly the stability of interpersonal coordination patterns performed in virtual settings.

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### 3.4.10 Differencial learning and random walk analysis in human balance

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Introduction: Human balance is often operationalised by the Center-of-Pressure (COP) trajectory in different stance conditions. Among the abundance of posturographic analysis methods, a lot of investigations are reduced to global parameters (Baratto et al. 2002) that quantify the amount of postural sway but miss to analyse the underlying behavioural structure. In fact, some research findings show that traditional parameters like mean, variance, and range are not sensitive enough to display postural changes in elderly or diseased persons (Horak 1997). The goal of this experiment was to compare some parameters including random walk analysis (Collins & De Luca 1993) and statistical methods in terms of their sensitivity of behavioural postural changes caused by differencial training (Schöllhorn 2000) and test conditions. Methods: COP sway of 4 healthy sport students (Ø 24,25 years (±2,36); Ø 182,25cm (± 6,8); Ø 68,05kg (±8,85)) was measured in 6 different stance conditions (eyes open/closed, single/two legged) of 30 sec. duration before and after the intervention. In addition, dynamic balance performance was tested on a wobble box for about 60 sec. 3 healthy sport students (Ø 24,6 years (± 3,06); Ø 178,67cm (± 9,07); Ø 71,6kg (± 9,07)) were included in the control group. The data analysis included 6 parameters: standard deviation, length, short- and long-term diffusion coefficients and short- and long-term hurst exponents (Collins & De Luca 1993). To quantify statistical group differences before and after the intervention a nonparametric analogy of the two-way variance analysis was applied. Results: In the pretest no significant differences were found between the groups. After intervention several parameters indicated significant group differences. While COP standard deviation did not reach the significance level ($p<0.05$), short-term diffusion coefficients ($p<0.001$) and the length of the COP ($p<0.01$) decreased significantly from pretest to posttest in the training group compared to the controls. However, only the diffusion coefficient could verify these results in the individual case. In addition, training persons enhanced their dynamic balance performance on the wobble box on average, while controls did not. Conclusion: The results show

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that random walk parameters are more sensitive to structural changes in postural behaviour according to training effects. The decline of the short-term diffusion coefficients indicates that the COP is less stochastic that means more deterministic in this temporal region. Thus differential learning seems to enhance the short time adaptability to little disturbances that arrive in quasi-static stance as was expected by the corresponding theory.

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### 3.4.11    Influence of magnetic insoles on drop jump capacity

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All systems on earth are permanently exposed to the geomagnetic field (30-70 µT). The importance of this surrounding field is shown in the orientation behaviour of animals. Despite some proof of influence on several physiological parameters [2, 3], an influence on humans is still strongly doubted. One reason for the rejection can be seen in a lack of understanding the influencing physical mechanism of weak static magnetic fields. A key problem is that the thermal-energy of the influenced molecules is normally bigger than the interaction-energy between the magnetic field and the molecules. However, if molecular reactions are in a time-window below the thermo-dynamical, fields down to strengths of 0,001T will cause changes in the hyperfine-coupling-behaviour of the triplett release of magnetosensitive molecules [4]. This induces mutations i.e. in the neurotransmitter release [1]. In the present study the influence of magnetic insoles (condition B) (0,08 T) on 12 healthy subjects was investigated on the drop-jump capacity from 24, 32, 40 cm height in comparison with non-distinguishable placebo insoles (condition A). 9 subjects jumped in an A-B-A-; 3 subjects in an A-A-A–design. Kinetic (Fa. Kistler) and EMG-data (Fa. Biovision) were recorded. Ground contact time, flight height, and the oscillations in medio-lateral and anterior-posterior directions were determined. The EMG-data were differentiated into 4 phases (preactivation, latency, reflex, voluntary con-

traction) and their RMS-values were analysed. Furthermore, the mean frequency in the phases was determined using a wavelet-transformation [6]. The analysis of variance was used for statistical verification. The kinetic data show no differences between the different conditions, whereas the EMG-data show a significant activation decrease of the lower limb muscles (mm. gastrocnemius medialis, soleus) in the latency- and reflex-phase. In the phase of voluntary contraction a significant decrease of the upper limb muscles (mm. rectus femoris, vastus lateralis) was observed with magnetic insoles. In the frequency progression no uniform results were found in the lower limb muscles. Some subjects react with an increase mean activation, others with a decrease. In the control-group no significant differences were detected. The decrease in the RMS-values can be coherent with the health state of the subjects. The insoles should only be worn in the case of injury or pain, which fit with the investigation of [5]. The unsteady reactions in the frequency domain can be explained with different activation levels of the subjects. Further investigations are necessary to show, how insoles can support or interfere human performance.

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## 3.5 Sport Science

### 3.5.1 A 3D analysis of circular swings on the men's competition mushroom.

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Scope: During the performance of Artistic Gymnastics exercises, the execution of a gymnast is evaluated considering the errors related to technique and body position (1). The reciprocal arrangement of the various parts of the body, and the different body positions in space, will determine the esthetic aspects of the exercise. Indeed, all parts of the body must harmonize to allow a successful and appreciated execution. We developed a method for the 3D analysis of body movements and positions during the performance of circular swings on the competition mushroom, an apparatus used by young gymnasts for pommel horse training. Preliminary data on five gymnasts are reported. Methods: Five experienced male gymnasts, all of national level, performed 30 circular swings on the competition mushroom. The 3D movements of 13 body landmarks were detected by an optoelectronic instrument (2). From landmark trajectories, technical measurements were obtained: diameters of ideal circles of ankles, hips, shoulders; deviation of the ankle diameters from circularity and from the horizontal plane; angle between shoulder, hip, and ankle. The values were used for a quantitative assessment of performance of the gymnasts. Results: At correlation analysis, standing height explained between 84 (ankle) and 20% (hip) of the inter-individual variation in the diameters; percentage of fat free mass explained between 65 (hip) and 30% (ankle) of the variation. Mean diameters were normalized (divided by standing height and percentage fat free mass, and multiplied by the mean values of the group). During the exercise, each ankle should follow a nearly horizontal circular path (deviation from circularity ranging from 3.6 to 6%, deviation from horizontality 9.4-19.7%), there should be an angle of approx 180° at the hips (actual values 146-153°), the shoulders should move as little as possible, and only in the lateral plane, without major anteroposterior movements (shoulder movement was 27-31% of ankle movement, hip movement was 16-20%). The analysis successfully ranked the gymnasts in accordance with conventional technical assessments. In conclusion, the method could help coaches and gymnasts indicating which parts of the body do not repeat a selected movement with sufficient accuracy, and quantifying the improvements obtained after a specific training program.

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### 3.5.2 The repeatability of body movements during a golf swing: a preliminary 3D analysis.

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Scope: To develop a method for the three-dimensional analysis of body movements during the performance of golf swing, and to investigate the repeatability of the trajectories of body landmarks in standardized conditions. Preliminary data on four golfers are reported. Methods: Four right-handed golfers (3 men, 1 woman, 30 to 51 years), all professionals of national level, performed 10 swings each in an indoor setting using a five iron. The golfers were asked to perform a "perfect" swing and hit a standard golf ball into a nylon net. The three-dimensional movements of 15 landmarks (13, body; 2, club) were detected by a 9-TVC optoelectronic instrument operating at 120 Hz (1). The repeatability of body movements was assessed by computing a standard deviation between standardized landmark trajectories (1). All the movement (address, backswing, impact and follow-through) was analyzed. All values were normalized for body dimensions. Results: The most repeatable body landmark was the left ankle (3.5 to 6.1 cm), the most variable were the wrists (right, 42.1 to 59.9 cm; left, 44.5 to 61.6 cm). In the lower limbs, repeatability was higher on the left (on average, 9.6 cm) than on the right side (14.3 cm); the converse applied to the upper limbs (right, 36.6 cm; left, 39 cm). Head trajectories were less repeatable than those recorded for the lower limbs (mean, 18.6 cm). On average, the total standard deviation was 26.3 cm (SD, 1.3). At ball impact, the velocity of the distal marker on the club ranged between 28.3 and 34.2 m/s. In golf, the players should reach various distances with their ball, using different clubs. A more repeatable body motion should reduce the uncertainty of the movement, and more expert golfers have been found to be more repeatable than novice players (2). On average, the present golfers had a good repeatability, but they performed the swing with different body movements. The present protocol can be used to individuate characteristic patterns of motion and to identify those parts of the body that do not perform with sufficient accuracy.

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### 3.5.3 Influence of training on electromyographical spectral parameters in exhausting swim bench exercises

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The adaptive spectral analysis has shown to be an useful method for analyzing electromyographical signals of muscle contractions in human movements (e.g. archery, Witte et al., 2001). In swimming isokinetic swim benches are used for training purposes and diagnostics in elite athletes. They allow for standardized comparable performance testing (Heller et al., 2004). The aim of this study is to examine the influence of training volume on electromyographical spectral parameters in exhausting swim bench exercises. Two female elite swimmers performed weekly tests on the isokinetic swim bench during the training process in preparation for the Olympic Games 2004 over a period of 22 weeks. The swimmers were asked to perform the butterfly arm stroke over 30 s with maximal effort on the swim bench. Electromyographical data of the m.tric.lat., m.tric.long. and m.lat.dorsi were acquired and mean mechanical power output (MPO) of the swimmers during the test was measured. The momentary median frequencies of the muscles were calculated for each stroke cycle by means of time-variant AR modeling (Arnold et al., 1998). The mean median frequency (MF) of the test resulted from the averaged momentary median frequencies of all cycles over a period of 300 ms. The training volume of the swimmers was quantified in distance per week (km). The Results show a decrease in swim bench performances (as MPO) after periods of high training volume (training camps) for both swimmers. Performances increase during the following taper periods prior to the competitions. The MF shows similar characteristics. In general high power outputs correspond to high frequencies especially for the m.tric.long. Further, a decrease in MF after periods of high training volume and an increase during the following taper period can be noticed. Correlation coefficients between values of MPO and MF of m.tric.long. reach from $r = 0.53*$ to $r = 0,83**$. Thus, relations between the performance in an exhaustive swim bench exercise and the EMG-frequencies of propulsive muscles (especially the m.tric.long.) can be observed during the training process in swimming.

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### 3.5.4 Effects of velocity on the coordination of cognitive map and idiothetic information during walking in athletes and sedentary subjects.

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Moving the body in the environment is a problem of navigation. This activity requires knowledge on the starting position, position of the goal to reach, of the pathways that can be used and the position during the displacement (Able, 1989). Navigation can actually mean two different kinds of processes: either using landmarks in the environment (piloting) or path integration (or dead-reckoning) using idiothetic information (vestibular system and proprioception). Through this study we were interested more particularly in this last process. Many works dealt with the estimation of a walking distance when blindfolded (Rieser et al. 1990; Loomis et al. 1993; Schwartz 1999; Mittelstaedt and Mittelstaedt 2001). The originality of our study lies in the fact that we compared two kinds of populations differing in terms of proprioception: athletes and non-athletes. Two groups of healthy volunteers took part in this experiment: 21 athletes and 20 non-athletes (both groups balanced for gender). Subjects were asked to walk to a target (10 m in front of them) that they had seen before being blindfolded at three different velocities (slow, normal, fast). We observed with the increase of the velocity a decrease of the distance walked for both groups. Both groups were very accurate at normal velocity (mean    SD, 10    1.01 m vs. 9.36    1.52 m for athletes and non-athletes, respectively). However, the athletes were also accurate at fast velocity (9.81    1.13 m). In both groups, the accuracy considerably decreased at slow velocity (12.19    1.77 m for athletes and 11.42    2.47 m for non-athletes). This work raises the problem of the relation or coordination between the representation of the environment (cognitive map) and the integration of idiothetic information during moving. It seems on the one hand that the velocity of a movement execution has an influence on the processing of proprioceptive information, and on the other hand that an intense physical activity increases the proprioceptive sensitivity of subjects.

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Keywords: athletes, non-athletes, cognitive map, path integration, self-motion perception, velocity, walking.

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### 3.5.5 Performance and kinematics in a hitting task of increasing intensity

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The aim of our study was to observe the coordination and the control solution adopted by confirmed and experts table tennis players when confronted to a continuous rhythmical hitting task, with increasing balls frequency (Fayt et al., 2004). Two groups of table tennis players (n=3 National ranking and n=5 Regional ranking) were required to execute a forehand drive towards a target (21 cm diameter), placed in the opponent half-table. Balls projection rate increased every 30 seconds (from 42 to 66 balls/min). Accuracy (% of balls hitting the target) and movement kinematics (goniometer placed on elbow joint, 100 Hz sample frequency, Biopac) have been recorded. Kinematics data were filtered using B-spline smoothing functions (Unser et al., 1993) and first and second order derivatives were calculated. Anova analysis were performed on performance and on movement time (MTabs), MT relative to the temporal window (MTrel), and maximal velocity (Vmax) of the hitting movement. Results confirmed a difference in performance between National and Regional players ($p<.001$). Regional players showed a significant decrease of performance through stages ($p<.01$) while no difference between stages has been detected for National players. For both groups, MTabs ($p<.05$) and intra-individual variability of MTabs ($p<.05$) decreased along stages (i.e. with increasing intensity). MTrel did not significantly differed between the 2 groups and along the stages ($p=.057$). Similarly, Vmax was not significantly different between the two groups and was not influenced by the balls ejection rate ($p = ns$). These results

demonstrate that experts could maintain a quite stable level of performance all along exercise, while the level of performance of confirmed players decreases with the increasing intensity. Analyses of movement kinematics suggest that balls frequency (1st task constraint) influenced absolute MT (but not MT relative to temporal window) whereas the required precision (2nd task constraint) influenced movement velocity.

Fayt V, Quignon G, Lazzari S (2004). Influence of exercise intensity on physiological parameters and on the drive execution in table tennis. In Science and Racket Sports III (Lees, Kahn and Maynard editors), pp. 25-30. London: Routledge.
Unser M, Aldroubi A, Eden M (1993). B-Spline Signal Processing: Part I-Theory. IEEE Trans. Signal Process., 41, pp. 821-832.

### 3.5.6     Speed-accuracy trade-off and internal constraints in a hitting task

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The aim of our study was to investigate how subjects manage with external (i.e., task) and internal (i.e., organism) constraints (Newell, 1986; Sparrow et al, 1998) during a continuous rhythmical hitting task in table tennis. We supposed that constraints interact and may change the subject action and, more precisely, that task repetition may change the adaptation form to task constraints. We manipulate task constraints by creating a speed-accuracy trade-off. Subjects (Experts, n=5 National ranking, vs. Novices, n=5) were asked to execute a hitting movement as precise to attain a target (21 cm diameter) placed on the opponent half-table and as fast to pass over a barrier (80 cm high, 2.50 m from the table). Moreover, they had to deal with three levels of difficulty: (i) task without displacement, or (ii) task with a predictable or (iii) unpredictable displacement. We retained for our analyses 5 performance outputs: (i) target attained and barrier passed (T+B), (ii) only the target (T) or (iii) only the barrier (B), (iv) the ball hitting the table attaining neither the target nor the barrier (O), and (v) all other situations (ball not hit or not reaching the opponent half-table) (N). HR was measured during all the tasks (heart rate monitor, Polar Accurex Plus). ANOVA analyses on accuracy were carried on to evaluate the improvements after 10 weeks of specific training (novices were tested before and after training, in the 3

difficulty conditions) and to analyse the difference between practice levels (novices vs. experts in the 3 task conditions).

Results confirmed the expected training (p<.05) and level of practice effects (p<.001) on performance. Two results retained our attention: (i) the relative distribution of the 5 performance outputs, before and after training for novice and between novice and experts, and (ii) the identical level of errors (N) for both levels of practice after training (p = ns). This latter could be explained by the fact that experts either meet all the requirements of the task -as they want to make sure of winning the rally- or they fail the task. On the other hand, novices face the conflict: be fast and/or be precise. Maintaining the double task constraints appeared to be an interesting training technique to avoid "diverted" behaviours and the use of different compensatory movements observed among non-expert players (Jospin and Fayt, 2004).

Jospin, L and Fayt, V (2004). Effort administration during increasing difficulty level training exercises in table tennis. In Science and Racket Sports III (edited by A. Lees, J.F. Kahn and I. Maynard), pp. 31-36. London: Routledge.

Newell, K.M. (1986). Constraints on the development of coordination. In Motor development in children: Aspects of coordination and control (edited by M.G. Wade and H.T.A. Whiting), pp. 341-360. Boston: Martinus Nijhoff.

Sparrow, W.A. and Newell, K.M. (1998). Metabolic energy expenditure and the regulation of movement economy. Psychonomic Bulletin & Review, 5(2), 173-196.

### 3.5.7 Identification of Movement patterns in handball throwing

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If movements are analyzed by discrete parameters, a subject's performance can be described in detail at given times or positions, but there is a lack of information concerning how the movement has been processed in-between. More detailed knowledge about the movement-processing becomes available if time-continuous data are analyzed. Based on a pattern recognition approach, analyses of the time courses of kinematic and dynamic variables have recently proved being useful to identify individual movement behavior as well as to investigate structural differences between slightly varying movements (e.g. Jaitner et al. 2001). Most of these studies deal with movements in which precision plays a subordinate role. In this study, a pattern recognition approach was applied to analyze handball throws on various targets. Furthermore, the throws were performed by players of a wide range of expertise. Five left-handed handball players (from beginner to national level) threw a handball at the penalty line to different sections of the handball goal. They performed 249 throws altogether. Three video cameras filmed the thrower's movements at 50 Hz. Time-courses of right hip as well as left shoulder, elbow, and wrist were determined using SIMI

Motion 6.0. Joint angles and orientation angles of the upper body as well as corresponding velocities were calculated. The distances between the time and amplitude normalized time courses were determined for all data sets according to Jaitner et al. (2001). Pattern analysis included cluster analyses of the distance matrices for various sets of variables using the ward algorithm. Cluster analysis yielded best results according to the level of performance, if the trajectories of hip, shoulder, elbow, and wrist in sagital plane were analyzed. 92% of trials were assessed correctly. Considering the trajectories of these joints marks in three dimensions, 63% of all trials were classified individually. Additionally, cluster analysis separated all trials of the best handball player in one cluster. No reasonable classification for movement direction could be identified. Because movement patterns of handball throwers on comparable levels of expertise are grouped in the same cluster, the results seem to support the theory of distinct stages in motor learning. Correspondingly, the clustering for the best player indicates a high stability of movement patterns by varying constraints. In comparison to earlier studies in track and field the recognition rates for individual movement styles are rather low but in a comparable range to analyses in other team sports.

Jaitner, T., Mendoza, L., & Schoellhorn, W. I. (2001). Analysis of the Long Jump Technique in the Transition from Approach to Takeoff based on time-continuous kinematic Data. European Journal of Sports Science 1[5]

### 3.5.8  Soccer scouting system on the basis of 10 year old players' thinking level

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In this lecture I would like to reflect that acquiring the special soccer routines – according to Schmidt - can only be based on variable practice. Variable practice means concrete operations in the theory of Piaget. However in team sports with this concrete operational solution you cannot reach high technical and tactical performance. To understand the development of that high technical and tactical performance, we have to ask the help of Piaget's developmental theory in which we are developing from concrete operational thinking to formal operational thinking. In this research we measured 10-13 years old soccer players with two special soccer test. Children soccer players' technical skills were tested in an exercise when a 3-meters long bench is turned on its side next to the wall with its legs, and the sitting surface was hit with the ball from 3 meters as many times as possible within a minute. The second test, which was recorded with video camera shows whether the player is at the concrete or at the formal operational

stage. In this test nine markers were placed around in equal distances shaping a circle. Eight children stood at eight markers, one of them with the ball. The ninth marker was empty. The task was to pass the ball to anyone except the child who was right next to him. After the pass he had to run to the empty marker. They had to pass the ball with one touch. The task was carried out successfully if the child passed the ball with one touch and ran to the right place in time. This may prove if the child is in formal operational stage. The task can be substituted in Piaget's logical system. The soccer task is according to the equivalence in this system. We detected that the evidential recognition of the game rule indicates the formal operational thinking. On the basis of the results my hypothesis has been verified, therefore in some special areas such as soccer the formal thinking can or must start at the age of 10. In my opinion those movements which can be explained by the schema (pattern) theory of Schmidt belong the concrete knowledge level of Piaget. For competition sports we have to select those children who - in their sports - use formal thinking already at 10 years age, as the operational coordination and systematically organized integration of the earlier acquired technical routines and of the environmental influences such as game rules.

Keywords: soccer, scouting, Piaget theory of thinking level, schema, INRC system

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### 3.5.9 Dynamic stretching of the lower extremities and somatic parameter: influence on countermovement jumps in mediocre trained tennis players?

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Stretching is often disregarded in leisure sports. Nevertheless, many people are training with high efforts and therefore risking injuries. Especially in conditional-coordinative sports, injuries are common due to inappropriate techniques, lack of prevention and risky behavior. In tennis, most injuries appear in the

lower extremities because of fast changes in speed and direction, jumps etc. Also, many players suffer from problems in the shoulder and neck, but in this study we concentrated on the lower extremities. Aim of the cross-sectional study was the determination of relations between somatic data, gender and jump performance, also influences of a dynamic stretching of the lower extremities were assessed. Test subjects consisted of 42 mediocre trained tennis players, 29 men, 13 women. Mean age of the test group was 29.5 years (±10.26), of the control group 30.1 years (±9.23). Mean height of the test group was 176.1 cm (±8.29), of the control group 178.7 cm (±9.64). Mean weight of the test group was 75.5 kg (±13.94), of the control group 77.7 kg (±16.13). Their mean tennis training consisted of 5.11 hours/week (±2.26). Independent variables were: age, height, weight, gender. Dependant variables were: jump height and time in countermovement jumps, assessed by a contact mat. Age, height and weight correlated highly significant with the jump performance. Male test persons achieved higher jump parameter than the women. Dynamic stretching had no significant influence on the jump performance.

Stretching had no effects in the test group because their muscles were not used to it. For general health and preventive reasons, people in leisure sports should care regularly for stretching.

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### 3.5.10 The influence of high blood lactate concentration on information processing stages

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Introduction: In many complex sports, quick and correct information processing is crucial for success. Information processing model of cognition assumes that environment information is processed through a series of three stages, each operating independently of the others. The three stages include the stimulus-identification stage, response-selection stage and response-programming stage (Proctor, Reeve and Weeks, 1990. A few minutes' long but very intense physical activity leads athletes to metabolic fatigue indicated by high plasma lactate. The results of many studies show improvements in speed of information processing which follows intense metabolic fatigue activity (McMorris & Graydon, 1996; Arcelin et al., 1997). But exercising protocols in that studies fail to reach very high lactate concentration as was described in some other sports studies

(Bosco, Luhtanen & Komi, 1983). The aim of this study is to investigate the influence of very high anaerobic lactate fatigue on separated information processing stages. Methods: Seventeen male right-handed students (mean age 21,5+-1,7 year) participated in the study. Participants performed three sets of treadmill walking with hands crossed at the back. The exercise sets lasted 2 min, except the last one, which was performed until voluntary exhaustion. Exercise sets were separated by 3 min resting periods. Before and after exercise, and during resting intervals, a simple and three-choice visual reaction task was administered. After all four information processing tasks blood samples were taken for lactate determinations. Motor responses to three different visual stimuli were short ($\Delta\varphi = 20°$), medial ($\Delta\varphi = 70°$) and long ($\Delta\varphi = 100°$) right elbow extension in transversal plane with no visual feedback. The EMG of triceps brachii-mediale head was recorded to determine simple short premotor time (ssPMT), simple long premotor time (slPMT), choice short premotor time (csPMT) and choice long premotor time (clPMT). Four dependent variables were used to calculate the time for response selection (RST) and the time for motor programming (MPT); RST = clPMT- slPMT, MPT = clPMT- csPMT. Results: Blood lactate showed an exponential increase during research protocol with maximal value after the last information processing stage (14,9   2,0 mmol/l). It was found that PMT decreased gradually as lactate reached its maximum. Response selection time decreased from 104,0 ms in rest to 74,7 ms in the third stage ($p < 0,005$). In the fourth stage it increased to 93,0 ms. Motor programming time was approximately 25 ms long with no statistically significant influence of exercising protocol on it. Discussion: We confirmed the results of some previous studies (Tenenbaum et al., 1993) that metabolic fatigue with high blood lactate concentration improved speed of information processing. With non-extreme blood lactate concentrations the improvements are mainly in decision-making processes. With extreme blood lactate concentrations only stimuli detection stage of information processing could improve.

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### 3.5.11 Human movement as a cultural shaped act

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Keywords: human movement, cycling, culture, system dynamic approach. The problem and occuring questions. Sport and human movement - even though they are important and essential elements of culture – have been and still are rather marginal within sport science, cultural studies and social sciences. But: sport matters besides text, symbols or language especially within perception, within change and within representation of culture. When we watch german cyclists - compared to japanese or mexican ones - you can surely say, that they move differently, even though both do actually nothing more than pedaling. Cycling could therefore be a human movement which is cultural formatted (Fikus & Schürmann, 2004). These thoughts or considerations lead to the following questions, which are going to be verified within this research project: •Is human movement (human, bodily acting) realisied differently depending on the cultural origin? Or: are there any invariants? •Are such differences or invariants recognisable in the body movement itself?

•And – if yes – what exactly is different or equal? Theoretical foundations in sport science, cultural studies and social sciences. The "theory of social practice" (Reckwitz, 2003) ist going to be one of the theoretical foundations, which try to explain the assumed questions, as well as the concept of habitus and incorporation (Bourdieu, 1982, 1987). Within sport scientific theories the project is based on the system dynamic approach and its modifications (Williams, Davids & Williams, 1999). The poster will show the results which have been recovered within the preliminary inquiry. This inquiry included a semantic differential to get individual meanings on cycling and a video-analysis of each individual cycling movement. The results are going to be connected to and discussed within the system dynamic approach.

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Williams, A. M., Davids, K. & Williams, J. G. (1999). Visual Perception and Action in Sport. Routledge: E & FN Spon.

## 3.6 Animal Locomotion / Biology

### 3.6.1 Gait analysis under nonlinear view point - applications to rehabilitation and sport

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The used nonlinear synergetic approach assumes that the motor control is characterized by only one or a few quantities at a macroscopic level while high complexity and numerous interactions of the subsystems (microscopic level) such as the nervous system, muscles, sense organs exist. For this reason, a large number of degrees of freedom in the human movement system can be controlled by a few collective variables or order parameters (Haken, 1996). The conclusion from this is that movement coordination, which exists at a macroscopic level, can be described by means of only a few parameters. A further advantage of the dynamic approach is the assessment of the movement variability as a property which is inherent in the system. In general, one essential problem in synergetics is the determination of the order parameter or the order parameters and their dynamics. For this, it is at first necessary to establish the number of the order parameters. Haas (1995) and Haken (1996) assume that cyclic, learned and automatic movements are governed by only one order parameter. They confirmed this hypothesis by a study of the learning process of drive a pedalo. An estimation of the number of order parameters was realized by means of the Karhunen-Loève-method (Haken, 1996). The aim of this paper is the determination of the number of order parameters by means of the KL-method for two cases: 1. Characterisation of walking coordination during rehabilitation with a knee joint endoprosthesis, 2. Characterisation of running coordination after prior cycling exercise in triathlon. The results of the study in rehabilitation show that the eigenvalues of the first KL-mode increase during the therapy. From this it can be concluded that the walking becomes more stable during the rehabilitation. Furthermore, an influence of a crutch on the individual movement coordination could be demonstrated. Changes in single kinematical parameters of running immediately after a cycling exercise show individual characteristics. Distinct trends are not noticeable. However, changes in the movement coordination on the basis of KL-method result in a decrease of variability due to the exercise. Triathletes are more capable of maintaining this movement variability during

the running exercise than the sports students. Furthermore, they show a more individual running style.

Haas R. 1995. Bewegungserkennung und Bewegungsanalyse mit dem Synergetischen Computer. Aachen: Shaker

Haken H. 1996. Principles of Brain Functioning. Berlin, Heidelberg: Springer

### 3.6.2 Application of a synergetic approach to equitation

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The problem of the recent kinematical researches in equitation is the impossibility discribing the horse-rider-system in its entirety. But the synergetic concept by Haken (1983) provides an opportunity to consider and model movements under the holistic aspect. This approach was applied to movement coordination in sport by Witte (2002). The whole movement results from the interaction between horse and rider, so that the horse-rider system provides one movement coordination, which presents oneself in a coordination pattern. Corresponding to the synergetic principle the horse-rider system can be described by one order parameter or a few order parameters. An estimation of the number of order parameters was realized by means of the Karhunen-Loève-method (Haas, 1995 and Haken, 1996). This method was used for the following requirement:

Distinguish between walk, trot and canter, One horseman rode 13 horses at working walk, trot and canter on a treadmill. The recordings were taken with the "Expert vision System" of Motion Analysis Corporation (Santa Rosa, California) by means of four cameras (120 Hz). For the motion analysis the essential marker positions of the left side of horse and rider were used. To calculate the KL-modes the horizontal velocities of all markers were estimated. By means of the horizontal velocity-time-course of the fore hoof the separation of the cycles were done. For each experimental condition 3 to 5 cycles were analysed. The KL-method were applied to all cycles and in this manner the eigenvalues of the single modes were determined. At first it can be find out that only the first two modes are of interest, because the eigenvalues of the 3rd KL-mode is smaller than 5 %. For all 13 horses it is recognised that in the case of the trot the 1. KL-mode is dominant. With this result it is proved that the movement coordination of trot can be described by only one order parameter. The clear distinction between trot and the both other gaits can be explained with the fact the trot is characterized by a diagonal synchronism. That means for example, the left fore hoof moves in the same time as the right back hoof.

Haas, R., 1995. Bewegungserkennung und Bewegungsanalyse mit dem Synergetischen Computer. Aachen: Shaker

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### 3.6.3 Gait pattern of the ataxic horse compared to the gait pattern of normal and sedated horses

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Ataxia is a common problem in equine medicine, and the mechanisms of ataxic gait are still only partially understood. Clinical examination is not specific in determining whether a horse is ataxic. In horses, mild sedation produces reversible ataxia. Measurements of the gait pattern of normal horses, ataxic horses, and sedated horses may facilitate the development of new methods of diagnosis and documentation. The aim of this study was to compare the limb coordination of normal horses, ataxic horses, and sedated horses. 15 horses with different degrees of ataxia were measured walking and trotting on a treadmill (Mustang 2200 KAGRA, Switzerland). The data of reflecting markers at four limbs were collected by 3D high speed video system with 120 Hz (Motion Analysis, Santa Rosa, CA). The horizontal movement of the markers was taken to calculate the autocorrelation function (ACF) of the left forelimb and the cross correlation (CCF) between the left forelimb and the three other limbs. The second maximum of the autocorrelation function was divided by the first, resulting in a value close to one for high consistency of the motion cycles and a value close to zero for low consistency. For statistical evaluation t-test for independent samples was used. At the walk and at the trot there were significant differences in the ACF and the CCF between ataxic and normal horses. Only the CCF between left fore and left hind limb at the trot was similar in the normal and ataxic horses. Interestingly, the CCF of the forelimbs of walking and trotting ataxic horses was significantly different from the CCF of the forelimbs of sedated horses. The results of this study may serve as a basic data set documenting the differences between the sedation induced ataxia and the naturally occurring ataxia. The differences between the groups can be used to aid in classification of the gait pattern of questionably affected animals.

## 3.7 Medicine / Rehabilitation

### 3.7.1 An optoelectronic 3D study of ankle and foot active range of motion in healthy young adults.

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Scope: During daily weight-bearing activities, body weight is transmitted to the ground through the tibiotalar and foot joints. These structures are continuously stressed, and they are involved in most acute injuries during sport performance. In this investigation, we assessed the normal ankle and foot range of motion (ROM) in a group of young healthy adults using the method developed in a previous study (1). Methods: Thirty healthy men (mean age 22.5 y, SD 3.4) and 35 women (mean age 23.8 y, SD 3.1) performed three repetitions of maximal ankle dorsiflexion and plantar flexion with the knee flexed at 90° and the leg suspended. Each limb was examined separately. Movements were detected using an optoelectronic instrument (2). Six markers identified the leg (tibial tuberosity, medial and lateral malleoli) and the foot (calcaneal tuberosity, dorsum of first and fifth metatarsal heads). For each anatomical plane, maximum leg and foot ROM were mathematically separated (2). Results: The sagittal plane movement (principal plane) was associated with frontal and horizontal plane motions. In males, the mean ROMs in the sagittal plane were 69° (right side), and 68° (left side). In females, the mean ROM was 71° for both sides. In the frontal plane, both males and females had mean ROMs of 17° (right side) and 15° (left side). In the horizontal plane, mean male ROMs were 18° (right side) and 16° (left side); the corresponding values in females were 20° and 19°. The movements were symmetric (Watson-Williams' test, $p > 0.05$ for all three planes and in both sexes), and no significant sex-related differences were found ($p > 0.05$ for all three planes and both sides). Intra-group variability was the lowest in the principal plane (CVs: sagittal plane, up to 4.4%; frontal plane, up to 7.1%; horizontal plane, up to 7.9%). In conclusion, the method was fast and not invasive, and allowed a complete measurement of the dynamic characteristics of the foot-ankle complex free from projection errors (2). Data can be used as normative values for the comparison of patients with alterations of the lower limbs.

1. Turci et al. Proc. EWOMS, Munster 2003, 73-74.
2. Ferrario et al. J Orthop Res 2002;20:122-9.

### 3.7.2 An optoelectronic study of the three-dimensional hip movements during treadmill walking.

*Chiarella Sforza, Michela Turci, Nicola Lovecchio, Yuri Francesca Shirai, Bruno Marelli, Virgilio F. Ferrario.*
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Scope: Walking is one of the most important weight-bearing activities performed by humans. In a previous study, we developed a method for the quantitative assessment of lower limb movements during treadmill running and walking (1). In this investigation, we assessed the normal hip movements during treadmill walking in a group of healthy adults. Methods: Thirty-seven healthy men (mean age 27 y, SD 10, range 19-57; mean standing height 177 cm, SD 6; mean weight 74 kg, SD 10; mean BMI 23.8 kg/m2, SD 2.7) and 35 healthy women (mean age 32 y, SD 12, range 19-66; mean standing height 167 cm, SD 5; mean weight 60 kg, SD 8; mean BMI 21.4 kg/m2, SD 2.3) walked at 1 m/s on a treadmill set at 0° inclination. Twelve steps were recorded for each subject using a 9-TVC optoelectronic instrument operating at 120 Hz (2). Nine markers identified the hip (right and left anterior superior iliac spines, sacrum) and the thighs (two sets of three markers). For the principal plane of movement, left and right hip joint ranges of motion were assessed (2). Results: In males, the mean movements in the sagittal plane (flexion-extension, direction of motion) were 54.7° (SD 1.3, right side), and 54.4° (SD 1.3, left side). In females, the mean movements were 53.6° (SD 1.1, right side), and 53.1° (SD 1.1, left side). The movements were symmetric (maximum intraindividual difference 15°, no side related differences; Watson-Williams' test, $p > 0.05$ in both sexes), and no significant sex-related differences were found ($p > 0.05$ for both sides). In both sexes, no significant relationships with age or anthropometry were found ($p > 0.05$ in all occasions). In conclusion, the method was fast and not invasive, and allowed a complete measurement of the dynamic characteristics of the hip during walking free from projection errors (2). Data can be used as normative values for the comparison of patients with alterations of the lower limbs, or with prosthetic reconstruction of the hip joint.

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### 3.7.3 Dissociation Between Time and Force Aspects of Dynamic Standing Balance

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Keywords: dynamic standing balance, symmetry, dissociation

Timing and force comprise two facets of movement control. The question of whether they are independent or interdependent has aroused research interest. Schmidt's (1999) generalised motor program proposed an independent view that selection of the level of force leaves timing unaffected. Sternad (2000) opposed this by showing that, in finger tapping, force variability decreased at faster tapping rates and timing variability decreased with increased force level. These two facets were however independent in Sternad's study in terms of their average magnitude. The present experiment revisits this issue in the context of human standing balance. For instance, during repetitive body weight shifting in the frontal plane, it is interesting to ask whether timing of left-right and right-left movements is independent of the vertical force developed by each leg. Nine patients with chronic hemiparetic stroke and nine controls were asked to repetitively shift their body weight on each leg at a comfortable pace. Vertical ground reaction force under each foot was recorded with two forceplates. On average the peak vertical ground reaction force reached 70 to 100 percent of body weight at intervals ranging from 761 to 2058 ms. We contrasted the intervals and forces produced in left-right and right-left weight shifting in terms of their ratios, i.e. temporal symmetry and spatial symmetry. ANOVAs revealed better lateral symmetry and less variability spatially than temporally ($F_{1,16}=16.618$, $p=0.001$) ($F_{1,16}=101.522$, $p=0.000$), and controls outperformed strokes ($F_{1,16}=2207.023$, $p=0.000$) ($F_{1,16}=169.210$, $p=0.000$). Coefficients of linear correlation on temporal and spatial symmetry were not significantly different from zero. These results indicate a degree of independence of control over timing and force aspects of balance. This demonstration of the dissociation between temporal and spatial symmetry, especially in the stroke population, is of clinical interest. In balance rehabilitation of patients with stroke much effort has been made to restore symmetric left-right and right-left vertical force in both static stance and weight shifting paradigms. Typically this involves providing visual biofeedback that focuses on spatial aspect of performance (for a review see Nichols, 1997). Although positive results have been reported, a lack of transfer from enhanced spatial symmetry in stance to temporal symmetry in dynamic gait has been noted (Winstein et al., 1989). One possibility is that this may be due to the lack of emphasis on timing during weight shifting training. We suggest a combined timing and spatial focus in future studies in rehabilitation of

dynamic standing balance.

### 3.7.4 Increasing noise improves signal-noise ratio in motor learning

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In traditional training-approaches (TT) the acquisition of a complex movement is achieved by many repetitions of the movement and reduced degrees of free-dom (Schneider, 1985). This approach seems to be doubtful if individuality of movement patterns, low probability of two identical movements (Schöllhorn, 2000) and necessity of noise for adaptable systems (Miglino, Lund, & Nolfi, 1995) are considered. In contrast the differencial learning-approach (DL) (Schöllhorn, 2000) amplifies the fluctuations during acquisition of the move-ment by manifold variations of the movement, which leads to better acquisition and retention performance (Beckmann & Schöllhorn, 2003). When the amplifi-cation of fluctuations is considered as increasing noise, analogies with phenom-ena in signal-theory become obvious. Random noise can enhance the detection and transmission of weak information-carrying signals (Hänggi, 2001) by a mechanism called stochastic resonance (SR). After research results showed that SR can be used to optimize motor control by adding subsensory mechanical noise it is asked if there are indications for SR phenomena in the acquisition of complex movements. In a pre-post-test-design 2 x 12 beginners (students, age: $22.1 \pm 3.8$) trained the shot-put for one month, twice a week. The post-test was carried out after the 8th training session. The retention-tests were carried out two and four weeks afterwards. The test was a shot put without approach. From each subject the average and the variance of three trials per test were given into the statistical analysis. The signal-to-noise ratio (SNR) was determined by di-viding the average put distance through the standard deviation of all three shot puts. During the intervention-phase group TT trained in accordance with a tradi-tional training-approach based on methical constant knowledge (Bauersfeld & Schröter, 1998). Group DL trained according to the conception of the DL-approach, where no movement task is repeated but the space of possible solu-tions in shot put is evaluated. The statistical analysis was carried out by an one-way ANOVA.

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Table 1. Representation of the experiment, the test-results and the statistical differences (n.s. = not significant; * = significant; ** = highly significant).

| | | acquisition (8 training- | | | | retention (no training) | | | |
|---|---|---|---|---|---|---|---|---|---|
| weeks | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th |
| test | | pre | | | post | | retention | | Retention |
| TT | Distance | 6,51m | | | 6,69m | | 6,51 | | 6,51 |
| | SNR | 45,50 | | | 35,73 | | 45,51 | | 38,96 |
| DL | Distance | 6,50m | | | 7,06 | | 7,16 | | 7,23 |
| | SNR | 41,83 | | | 50,67 | | 61,66 | | 127,20 |
| statistical differences | Distance | n.s. | | | ** (p= .01) | | ** (p= .01) | | ** (p= .01) |
| | SNR | n.s. | | | n.s. | | n.s. | | ** (p= .004) |

Table 1 shows that DL leads to better acquisition, retention and increasing SNR. A possible interpretation is that adding noise up to a certain amount in motor skill acquisition leads to a stronger output-signal. Whether further increase of noise will lead to a decrease of the ratio in order to verify the SR phenomenon on the motor level, demands further research.

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### 3.7.5 Effects of psychomotor training on locomotion in old age

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Falls in the elderly were ascribed to several factors such as cardiovascular, muscular, vestibular and cognitive deficits. In order to develop an adequate intervention program, we quantified the influence of a regular psychomotor training on locomotion and the associated cognitive costs in young and elderly subjects using a dual-task design. The psychomotor training in Exp. A and B involved motor components such as muscle strength, flexibility, coordination and balance as well as cognitive skills such as memorizing names or reproducing clapping rhythms. Dual-tasks were excluded from the training in order to avoid transfer to the experimental testing. Cross-sectional study (Exp. A): 12 young subjects, 17 non-exercised elderly and 12 exercised elderly attending a psychomotor training once a week for about 4 years, participated in the experiment. A loco-motor task (walking a distance of 25 m), a fine-motor task (buttoning and unbuttoning an experimental jacket with 9 different buttons) and a cognitive task (memorizing a sequence of ten geometric symbols) were performed as single tasks and as dual tasks (walking and buttoning, walking and memorizing). Tasks were carried out in a counterbalanced order. Intervention study (Exp B): 13 elderly subjects attending a three months` psychomotor training and 10 elderly subjects attending a control group participated. The training program took place for 60 min once a week, the control group only attended pre- and post-testing. Prior to and at the end of the training subjects performed the same single and dual tasks as described in Exp. A. In Exp. A we found a significant single-task difference between the young and non-exercised elderly in walking velocity, fine-motor and memory performance, whereas there was no difference between young and exercised elderly. Dual task costs were the same for all groups. In Exp. B a training effect was observed only for walking while buttoning. Dual task costs were the same for both groups. The results suggest that long- but not short-term psychomotor training may alleviate age related deficits of motor and cognitive functions. It should be noted that an increase of walking velocity found in the exercised elderly might represent a safer walking pattern, as according to Whipple and Wolfson (1989)1 individuals with a walking velocity less than 0.45 m/s might be classified as fallers.

1Whipple R, Wolfson LI (1989) Abnormalities of balance, gait and sensorimotor function in the elderly population. Balance 61-68

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