RE-learning Perception-Action In Rehabilitation from a Systems perspective

Closing Conference

Department of Human Movement Sciences

University Medical Center Groningen, Groningen

28-30 August 2024

Programme & Book of abstracts

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska - Curie grant agreement No 956003

How to reach the meeting room (Rode Zaal) at the UMCG

1. Enter the main entrance of the UMCG (Hanzeplein 1) (You will see that you can walk straight either from the left or the right side).
2. Take the left side (Fonteinstraat) and walk straight until you reach the fountain and the café.
3. If you walk past the fountain, you will find a street on your right with different shops (Winkelstraat). There, you will find an elevator and stairs on your left hand that can take you to other floors.
4. Go the second floor and turn right and then immediately right on the first corridor (you can also follow the signs for **Rode Zaal**). After a few meters you will see an open space with a coffee machine, tables and chairs on your left with a door on the left corner. The rode zaal is in that door.

Wednesday 28 August 2024

Location: Rode Zaal, UMCG

09:15 – 09:30 Coffee available at the Blauwe Patio

09:30 – 10:00 Welcome by the REPAIRS Coordinator Raoul Bongers

10:00 – 11:30 Session I: Oral presentations REPAIRS PhD students
Chair: Lei Zhang, *Ruhr University Bochum*

10:00-10:20 Danial Borooghani, *Aix-Marseille University*
A nonlinear dynamical model of the angle-of-approach effect in manual lateral interception

10:20-10:40 Amirhossein Esmaeili, *Aix-Marseille University*
Probing other's Presence: Probabilistic Inference Across Brain Scales Reveals Enhanced Excitatory Synaptic Efficacy

10:40-11:00 Marijn Hafkamp, *Aix-Marseille University*
From independent individuals to an interdependent team: learning to coordinate with others in a manual ball-and-beam task

11:00-11:20 Anaëlle Cheillan, *University of Lisbon*
An original ACL rehabilitation game based on coordination to improve postural stability

11:30 – 12:00 Break *(Location: Blauwe Patio, UMCG)*

12:00 – 12:30 Session II: Translation to rehabilitation from an industry perspective 1
Chair: Raoul Bongers, *University Medical Center Groningen*

Frans Steenbrink, *Motek Medical*
Rehabilitation technology to improve gait & balance – from research to clinical practice

12:30 – 13:30 Lunch (*Location: Blauwe Patio, UMCG*)

13:30 – 15:00 Session III: Ecological Psychology
Chair: David Jacobs, *Autonomous University of Madrid*

13:30-14:00 William Warren, *Brown University*
Perception-Action Coupling in Collective Dynamics

14:00-14:30 Benoit Bardy, *University of Montpellier*
How moving in unison can enhance social interaction in physical and digital realities.

14:30-15:00 Paula Silva, *University of Cincinnati*
Ecologically-Inspired Perception-Action Research: A Catalyst for a Rehabilitation Practice that Celebrates Movement Diversity

15:00 – 16:00 Poster presentation session (*Location: Blauwe Patio, UMCG*)

16:00 – 16:30 Break

16:30 – 18:00 Session IV: Ecological Psychology & Dynamical Systems and applications
Chair: Frank Zaal, *University Medical Center Groningen*

16:30-17:00 Matthew Rodger, *Queen's University Belfast*
Catching and throwing without vision: auditory-motor coordination in people with visual impairments

17:00-17:30 Ludovic Seifert, *University of Rouen*
Learning & Affordances: an Ecological Dynamics approach

17:30-18:00 Denis Mottet, *University of Montpellier*
A multidisciplinary perspective on stroke rehabilitation

19:00 Conference Dinner (*Location: Restaurant 't Feithhuis, Martinikerkhof 10, 9712 JG Groningen*)

Thursday 29 August 2024

Location: Rode Zaal, UMCG

09:15 – 09:30 Coffee available at the Blauwe Patio

09:30 – 11:30 Session I: Oral presentations REPAIRS PhD students

Chair: Reinoud Bootsma, *Aix-Marseille University*

09:30-09:50 Anadi Mehta, *University Medical Center Groningen*
Influence of Variability in Search for New Movement Coordination Patterns

09:50-10:10 Saroosh Bilal, *Autonomous University of Madrid*
The use of electronic aids by visually impaired individuals in unfamiliar environments: a qualitative study

10:10-10:30 Samruddhi Damle, *University Medical Center Groningen*
Can we perceive interceptability for oneself?

10:30-10:50 Wanxiong Cai, *Ruhr University Bochum*
Investigating coordination of muscles during planar arm reaching movements

10:50-11:10 Giacomo Bressanello, *University Medical Center Groningen*
The Different Practice Effects on Reaching Tasks Involving Geometric and Dynamic Affordances

11:30 – 12:00 Break (*Location: Blauwe Patio, UMCG*)

12:00 – 12:30 Session II: Translation to rehabilitation from an industry perspective 2

Chair: Raoul Bongers, *University Medical Center Groningen*

Melvyn Roerdink, *Vrije Universiteit Amsterdam*
Augmented-reality technology translated to real-world therapy through public-private partnerships

12:30 – 13:30 Lunch (*Location: Blauwe Patio, UMCG*)

13:30 – 14:30 Poster presentation session (*Location: Blauwe Patio, UMCG*)

14:30 – 15:30 Session III: Philosophical underpinnings perception-action
Chair: Joanne Smith, *University Medical Center Groningen*

14:30-15:00 Rob Withagen, *University Medical Center Groningen*
What is this thing called environment? Gibson and his critics

15:00-15:30 Erik Myin, *University of Antwerp*
Perception, action and history

15:30 – 16:00 Break (*Location: Blauwe Patio, UMCG*)

16:00 – 17:00 Session IV: Rehabilitation, Movement Science and Technology
Chair: David Travieso, *Autonomous University of Madrid*

16:00-16:30: Dario Farina, *Imperial College London*
NeuroMechanics of Human Movement and Neural Interfacing: A Spinal Motoneuron-Centric View

16:30-17:00 Han Houdijk, *University Medical Center Groningen*
Co-adaptation of assistive technology: taking the human in the loop

18:00 Meet-up for transportation to the restaurant (*Pick-up location: Martini hotel, Gedempte Zuiderdiep 8, 9711 HG Groningen)*

18:30 Conference Dinner (Location: Restaurant "De Twee Provinciën", Meerweg 245, 9752 XD Haren)

22:30 Transportation back to Groningen

Friday 30 August 2024

Location: Rode Zaal, UMCG

10:15 – 10:30 Coffee available at the Blauwe Patio

10:30 – 11:30 Session I: Oral presentations REPAIRS PhD students session
Chair: Gregor Schöner, *Ruhr University Bochum*

10:30-10:50 Chiara Basaglia, *MEDIAN*
Socioeconomic Benefits of Medical Rehabilitation

10:50-11:10 Alessandro Bonfiglio, *Euleria Health*
IMU Sensor-to-Segment Calibrations for Upper Limbs Joint Angle Estimation in Rehabilitation

11:10-11:30 Giulia Di Rienzo, *University of Antwerp*
Bringing the context back to life: Conceptual and practical reflections on the systems perspective

11:30 – 12:00 Break (*Location: Blauwe Patio, UMCG*)

12:00 – 12:30 Session II: Translation to rehabilitation from an industry perspective 3
Chair: Raoul Bongers, *University Medical Center Groningen*

Jasper den Boer, *Umaco BV*
Bridging science and commerce

12:30 – 13:30 Lunch (*Location: Blauwe Patio, UMCG*)

13:30 – 14:30 Poster presentation session (*Location: Blauwe Patio, UMCG*)

14:30 – 15:30 Session III: Translation in perception and in action
Chair: Erik Myin, *University of Antwerp*

14:30-15:00 Claudia Voelcker-Rehage, *University of Münster*
From basic science to clinical applications in motor control research

15:00-15:30 Russell Chan, *University of Twente*
Quantifying the individual in motor sequence learning: Using multimodal data to enhance theoretical understanding

15:30 – 16:00 Break (*Location: Blauwe Patio, UMCG*)

16:00 – 17:00 Session IV: Implementation and effectiveness of rehabilitation technology
Chair: Raoul Bongers, *University Medical Center Groningen*

16:00-16:30 Gerdienke Prange, *Roessingh Research and Development Enschede*
Effect of using a grip-supporting glove as assistive device with ADL: the promise of soft-robotics?

16:30-17:00 Corry van der Sluis, *University Medical Center Groningen*
Add value and reduce waste in research: patient engagement and implementation

17:00-17:30 Closing session

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Oral presentations

REPAIRS PhD students

A nonlinear dynamical model of the angle-of-approach effect in manual lateral interception

Danial Borooghani[1], Remy Casanova[1], Frank T.J.M. Zaal[2], Reinoud J. Bootsma[1]

[1] *Institut des Sciences du Mouvement, Aix-Marseille Université, CNRS, Marseille, France*

[2]*Department of Human Movement Sciences, University Medical Center, Groningen, Groningen, The Netherlands*

It has been demonstrated that the control of manual lateral interception tasks has a prospective rather than predictive nature. This matter manifests itself prominently in the systematically different kinematics of hand movement for targets moving uniformly and arriving at the same interception position with the same flight duration time while starting to move from different points. This phenomenon is the angle-of-approach effect (Ledouit et al., 2013) and suggests that both ball position and ball velocity affect the motor control of the hand movement toward the future interception point.

For the purpose of modelling this movement, since the existing linear dynamical models could not adequately capture the empirically observed hand kinematics, an information-driven nonlinear dynamical model is developed. Combining conservative Duffing stiffness with both Rayleigh and Van der Pol nonconservative terms allowed the generating of discrete movements with the required kinematic characteristics. Visual guidance was incorporated by (i) the (perceptually specified) current interception location aimed for and (ii) scaling the model parameters to the (perceptually specified) time-to-contact of the target with the interception axis. The former, as a stand-in based on a combination of current ball position and velocity, evolves over time and thereby results in the emergence of the angle-of-approach effect. The model could adequately capture a dataset of empirically observed hand kinematics incorporating 28 different target trajectories under four different ball velocity (and hence time pressure) conditions. We conclude that information-movement coupling in the form of a principled information-driven nonlinear dynamics-based model with as few as six coefficients can adequately capture the richness of behaviour observed in manual lateral interception tasks.

Probing other's Presence: Probabilistic Inference Across Brain Scales Reveals Enhanced Excitatory Synaptic Efficacy

Amirhossein Esmaeili[1], Marie Demolliens[3], Marjolein Viersen[4], Abolfazl Ziaeemehr[1], Faical Isbaine[5], Sylvain Takerkart[2], Pascal Huguet[3], Frank Zaal[4], Victor Jirsa[1], Driss Boussaoud[1], Meysam Hashemi[1]

[1]*Institute of Systems Neuroscience, Aix-Marseille University, Marseille, France*

[2]*Institute of Neuroscience in Timone, Aix Marseille Université, Marseille, France*

[3]*Laboratory of Social and Cognitive Psychology, Clermont-Ferrand University, France*

[4]*Department for Human Movement Sciences, University of Groningen, Groningen, the Netherlands*

[5]*Departments of Neurosurgery, Emory University, Atlanta, United States*

The mere presence of others is integral to social cognition and is a major modulator of task performance. However, the mechanisms through which mere presence exerts such modulations on behavior remain poorly understood. This study bridges this gap by examining how mere presence of others alters synaptic efficacy across three spatio-temporal brain scales in subject groups comprising of Monkeys and Humans. Monkeys performing a cognitive task exhibited increased activity in brain regions associated with attention. Similarly, the female subject group in Humans displayed improved task performance during the presence condition, which was subsequently linked to increased synaptic efficacy within Dorsal and Ventral attention networks. We propose that this attentional modulation via distractor suppression is driven by enhanced effective connectivity between attentional brain regions/networks. Our findings provide a novel neurobiological framework for mere presence effects and their potential implication in social neuropathologies such as Autism Spectrum Disorder or Schizophrenia.

Exploring the process of interpersonal coordination using a novel (solo/joint) ball-and-beam task design

Marijn S.J. Hafkamp, Remy Casanova, Reinoud J. Bootsma
Aix-Marseille Université, CNRS, Marseille, France

In daily life we often engage in joint activities. To do this successfully, we have to learn how to Many daily life activities require interpersonal coordination (IPC). According to the ecological-dynamical approach, IPC has a synergistic structure across individuals. Not much is known, however, about the acquisition process that leads to such interpersonal coordinative structures. To address this issue, we designed a novel perceptuomotor task that is not only dynamic and functional, but also sufficiently challenging for a learning process to be required. In this task, to which we refer as the manual ball-and-beam task, agents learn to roll a ball as fast and accurately as possible between two targets on a long, hand-held beam. In a first experiment with this task, we found evidence for Bernstein's learning stages of freezing and freeing of degrees of freedom on an interpersonal level. This suggested that the acquisition of IPC could be understood with the same concepts as individuals motor learning. In a second series of experiments, we explored the alternative hypothesis that the acquisition of IPC should be understood as a transition from independent individuals to an interdependent team. Employing the fact that the ball-and-beam task could be performed in a solo as well as in a joint setting, we investigated the solo-to-joint transfer of several pertinent indicators of performance, such as the number of target hits and the timing of the beam movement. In doing so, we developed an methodology to quantify what each individual brought to an interaction, and what emerged from that interaction. We conclude that the ball-and-beam design provides a unique way to explore not only the structure, but also the acquisition process of interpersonal coordination, which may be characterized in different ways.

An original ACL rehabilitation game based on coordination to improve postural stability

Anaëlle Cheillan[1], João Milho[2], Pedro Passos[3]

[1]*Faculdade de Motricidade Humana, Universidade de Lisboa, Portugal*

[2]*CIMOSM, Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Portugal*

[3]*CIPER, Faculdade de Motricidade Humana, Universidade de Lisboa, Portugal*

Postural stability deficits after an ACL injury result from alterations in perception-action couplings (Furlanetto et al., 2016) and should be addressed from a systems perspective (Dischiavi et al., 2020). Accordingly, we designed a joint-action game involving both inter-limb and inter-participant coordination to help ACL patients relearn perception-action and consequently improve postural stability. The main feature of this game lies in the informational and mechanical couplings that exist between the lower limbs and between the participants, and therefore, in the synergy formation such couplings should foster. As synergies are low-dimensional entities (Bernstein, 1969), it was hypothesized that healthy and injured elements (in both body and dyad systems) should compensate each other's variability during joint action. Through reciprocal compensation mechanisms, our joint-action game was expected to be clinically relevant.

Using methodologies inherent to a systems perspective, our game was tested in 12 healthy dyads to assess its clinical potential in terms of (1) postural reorganization and (2) emerging coordination. (1) Players with higher performance demonstrated less periodicity in their postural oscillations (i.e., higher sample entropy) allowing an increased ability to resist to perturbations threatening postural stability. (2) Relative phase between the angular positions of left and right knees was analyzed. A two-component PCA analysis based on the distribution of nine relative-phase regions revealed a cluster in the lower-limb coordination strategies adopted by players with lower performance. At the inter-participant scale, the uncontrolled manifold (UCM) method (Scholz & Schöner, 1999) was used to investigate whether reciprocal compensation between the players' hand motion in the vertical plane occur to stabilize the board center height. Interpersonal synergies, defined as the presence of such a functional reciprocal compensation, emerged with the improvement of performance. Such findings encourage us to test our game as a rehabilitation device. Translation aspects were explored during a two-week experience in clinics.

Influence of Variability in Search for New Movement Coordination Patterns

Anadi Mehta[1], Joanne Smith[1], David Travieso[2], Raoul M. Bongers[1]

[1]*Department of Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands*

[2]*Facultad de Psicología, Universidad Autónoma de Madrid, Madrid, Spain*

Motor learning involves the search for task specific coordination patterns of joint angles. The role of variability has been predominantly studied on task performance and there is insufficient insight on how it modulates learning. This project delves into how variability influences search behaviour both at task and joint level during acquisition of novel movement coordination patterns in de-novo learning. There are primarily two sources of variability – externally imposed through the task during practice (extrinsic) or inherent flexibility in movements of each individual (intrinsic). We hypothesized that participants with greater variability would exhibit higher search behaviour and more adaptable learning. The first study focused on extrinsic variability through the ordering of different practice conditions. A virtual lateral interception task using body machine interface was conducted with blocked and random practice groups. A redundant mapping was introduced between the upper limb joint angles and the virtual paddle position such that the participants had to learn novel joint angle coordination patterns to accurately control the paddle for interception. Results showed that task performance was independent of practice conditions. As hypothesized, random practice resulted in higher variability in both task-relevant and task-irrelevant spaces throughout each learning phase. This enhanced search behaviour both at task and joint level led to the formation of more diverse joint coordination patterns. A follow-up study focuses on the added influence of intrinsic variability in search. Task irrelevant variability in a reaching task with occasional target jumps was used to categorize participants based on their intrinsic variability. These participants then performed the same learning task as in the previous study. Initial results indicate no effect of intrinsic variability on task performance but change in search behaviour across training is higher for participants with low intrinsic variability. These studies show that variability enhances search behaviour resulting in more diverse coordination patterns.

The use of electronic aids by visually impaired individuals in unfamiliar environments: a qualitative study

Saroosh Bilal[1], Jorge Rebate[2], Verónica Sevillano[1], David M. Jacobs[1]

[1]*Universidad Autónoma de Madrid, Spain*

[2]*Fundacion ONCE, Madrid, Spain*

Unfamiliar environments are challenging for navigation and exploration, particularly for those who are blind. Based on a user-centered approach, a qualitative was conducted aimed to understand challenges of blind individuals in unfamiliar environments (hotels) and the utility of sensory substitution devices (SSDs) in this environment. Eight semi-structured interviews were carried out with blind individuals (mean age 39 ± 12 years ; 5 males and 3 females) and analyzed through thematic analysis conducted by using Atlas.ti software. The total number of verbatims-full significant excerpt (N = 253), refers to the exact, word-for-word transcription of the spoken words of participants, were coded into subthemes and themes. Three major themes were identified: 1. Navigation and orientation; (30% of total verbatims), related to the navigational difficulties through lack of understanding of localized and global positioning, complex open structural layouts in indoor unfamiliar spaces, and inaccessibility of buildings; 2. Wayfinding technologies and aids (33.6%) related to characterization of wayfinding aids and devices and there were mentions of utility of devices (SSDs and others) and aids as well as lack of utility arising due to device design (bulky, multiple components etc.), provision of inappropriate amount of information (overload/ limited information), lack of user centric design approach, need of training and practice additionally participants indicated social evaluation concerns with the rehab aids; 3. User's needs; made up 36.4% of the total verbatims indicated towards user's needs regarding the environment such as autonomy (provided by understanding the environment, exploration, compatibility), control over environment, and sociability.

Can we perceive interceptability for oneself?

Samruddhi Damle[1], Reinoud Bootsma[2], Frank Zaal[1]

[1] *University Medical Centre Groningen (UMCG), the Netherlands*

[2] *Aix Marseilles University (AMU), France*

This study aimed to characterize the affordance of interceptability for oneself using a manual lateral interception paradigm. We asked a two-fold research question; One, what makes a virtual ball interceptable or not? Two, how reliably can individuals perceive this affordance for themselves? We hypothesized that a spatiotemporal boundary would determine the interceptability of a ball, and individuals would be capable of accurately perceiving this boundary for themselves. Fifteen right-handed participants were first trained on a manual lateral interception task. Subsequently, they were tested on two experimental sessions presented in a randomized and counterbalanced order. In the action session, participants were instructed to intercept as many virtual balls as possible. In the judging session, they gave verbal "No"-calls when they perceived a ball to be uninterceptable while attempting to make interceptions. Analyses using generalized linear mixed modeling revealed significant effects of three factors on interceptability: distance from start to the interception location, ball flight times and the approach angle of the ball. The spatiotemporal boundary (made up of the distance and ball flight times), as hypothesized, co-determined actualized interceptability. Surprisingly the ball's approach angle also significantly predicted the actualized interceptability. Additionally, we found that participants were able to perceive this affordance for themselves with 75% accuracy, which was also replicated by our model. These results suggest that individuals can indeed know their own abilities to intercept a virtual ball, and equally know when the ball is beyond their reach. Lastly, we showed that perceiving and actualizing of interceptability for oneself are characterized by a handful of shared variables, in turn demonstrating the perception-action coupling in this lateral interception paradigm. Further analyses on the underlying optical variables are ongoing. The overarching objective is to formulate the informational account of the affordance of interceptability for oneself.

Investigating coordination of muscles during planar arm reaching movements

Wanxiong Cai, Lei Zhang, Gregor Schöner

Institut für Neuroinformatik, Ruhr-Universität Bochum, Germany

Skeletal muscles are believed to function as groups, i.e., muscle synergies, to produce movements. These synergies given by applying matrix factorization to electromyography (EMG) data help understand motor control by grouping muscles into fewer motor modules, but such fixed sharing patterns alone don't explain why this redundancy exists. Studies at the joint level have shown that redundancy is crucial for achieving stable end-effector outcomes through the coordination of joints. We are inspired to investigate if similar coordination exists between muscles during arm movements. A planar arm reaching task is used where participants keep the wrist, elbow and shoulder joints in a horizontal plane and move their hands from starting locations to target locations displayed on a screen. Potential compensatory coordination of muscles can help maintain desired joint torques to accomplish the movements precisely according to the idea of the uncontrolled manifolds (UCM) hypothesis. Because the biomechanical model of joint torque production is too complex for UCM analysis, we conduct a pair-wise correlation analysis of muscle activation. We hypothesize that a negative correlation between the activation of agonists and a positive correlation between the activation of antagonistic muscles should be observed if such coordination exists. However, our results of correlation analysis of EMG don't show significant compensatory effects. These negative reports indicate that this pair-wise correlation analysis is not adequate for capturing the structure of variances of muscle activation. We are motivated to develop a method for UCM analysis at the muscle-torque level for the next step.

The Different Practice Effects on Reaching Tasks Involving Geometric and Dynamic Affordances

Giacomo Bressanello, Naomi A. Schreurs, Raoul M. Bongers, Joanne Smith

Department of Human Movement Science, University Medical Center Groningen, University of Groningen, the Netherlands

Affordances are the opportunities for action provided by the environment and can be perceived. Research indicates that with practice, individuals become more accurate in perceiving affordances. However, the learning process may vary depending on whether the affordances are related solely to body geometrics or also involve action dynamics. Here, we aimed to identify differences in learning patterns between geometric and dynamic affordances in a reaching task. Participants were divided into two groups: arm-only reach (geometric affordance) vs arm-and-torso reach (dynamic affordance). Both groups were asked to estimate their maximum reachable distance to a cup (perception) and then attempt to reach and grasp the cup (action). The cup's position was adjusted with a pulley system, and end-effector kinematics were recorded. The study included a pre-test, two-block practice phase, and post-test design. Results showed that perceived reaching ability (PRA) improved from pre-test to post-test in both groups, and that arm-only PRA was less than arm-and-torso PRA. Additionally, variability significantly decreased between early and late practice blocks for both groups, and variability was lower in the arm-and-torso condition compared to the arm-only condition. Furthermore, we managed to characterize the changes found during practice into different clusters, so people vary in learning to perceive affordances. Not all patterns led to discovery of affordances. The current study indicates the relevance of examining learning routes of affordances.

Socioeconomic Benefits of Medical Rehabilitation

Chiara Basaglia, Laura Golenia, Thomas Preuss
MEDIAN Unternehmensgruppe, Germany

Rehabilitation has significant socioeconomic implications, influencing individuals' productivity, quality of life, and social participation. Inpatient rehabilitation market is growing due to aging of population, increased morbidity due to medical advances and extended work life. However, rehabilitation often lacks adequate acknowledgement as a fundamental pillar of the healthcare system. The aim of the project is to provide concrete evidence of the economic and social value of rehabilitation in Germany. By analysing data from MEDIAN's rehabilitation and follow-up care services, I aim to quantify the benefits of rehabilitation in terms of return to work, improved quality of life, reduced social isolation, and enhanced self-sufficiency in daily activities.

The patients considered in this analysis are from the orthopedic, pulmonology, and cardiology departments. I examined various aspects of the Work Ability Score (WAS), a Patient-Reported Outcome Measure (PROM) that evaluates worker productivity. Additionally, I constructed a Bayesian model to explore the associations between WAS and specific patient data, which could play a crucial role in improving or worsening patients' work ability. For this last analysis the patients were divided based on gender.

I started evaluating other PROMs of the different departments: the Pain Scale, which is used for assessing the patient´s pain severity, in Orthopedy. Moreover, I utilized the VR-12, a self-assessment questionnaire that measures health-related quality of life, taking into account both physical and mental health, and a standardized Patient Satisfaction Questionnaire filled by patients after the rehabilitation, defined by payor.

IMU Sensor-to-Segment Calibrations for Upper Limbs Joint Angle Estimation in Rehabilitation

Alessandro Bonfiglio[123], Elisabetta Farella[3], Raoul M. Bongers[4]

[1]*Department of Information Engineering and Computer Science (DISI), University of Trento, Trento, Italy*

[2]*Euleria Health srl, Rovereto, Italy*

[3]*Energy Efficient Embedded Digital Architectures (E3DA), Fondazione Bruno Kessler, Trento, Italy*

[4]*Department of Human Movement Sciences, University Medical Center Groningen, Groningen, The Netherlands*

Sensor-to-segment calibration consists of aligning the internal reference frame of an Inertial Measurement Unit (IMU) with the anatomical reference frame of the body segment to which it is attached. This process is critical to ensure accurate and clinically meaningful measurements of joint angles. This work presents and overview of three separated papers that compare the accuracy of the most common types of calibrations presented in literature, namely N-pose (NP), functional calibration (FC) and manual alignment (MA), for the estimation of humerothoracic, elbow and wrist joint angles. 13 subjects were instrumented with a set of 5 IMU and 5 optical 3-maker clusters. After the calibration procedure, each subject performed a sequence of single-plane/single/joint and multi-plane/multi-joint tasks. Range of Motion (ROM) error, Root Mean Squared Error (RMSE) and Offset were used as metrics to compare the accuracy of the IMU joint angles computed with each calibration type against and optical motion capture system. Three-way RM ANOVAs were conducted on each metrics to assess the effect of calibrations, tasks, and joint axes. Humerothoracic joint angles demonstrated no significant differences across calibrations, thereby recommending NP as the preferred calibration method for the shoulder joint. Elbow joint angles showed the lowest RMSE and offset for MA, making this the preferred calibration method for the elbow. Wrist joint angles showed minor significant differences across calibrations, where FC displayed the lowest RMSE and ROM error and, thereby, being the preferred calibration for the wrist. Collectively, these studies underscore the potential of IMUs in clinical rehabilitation settings, offering insights into optimal calibration methods for accurate and reliable joint angle measurement for different joints during various movements and across all 3D joint angle axes.

Bringing the context back to life: Conceptual and practical reflections on the systems perspective

Giulia Di Rienzo
University of Antwerp, Belgium

With the advent of embodied and embedded approaches to cognitive science, there is a growing recognition of how environments shape human behavior. Traditional views in cognitive science perceive the "organism-environment" relationship as a compound of two distinct and mutually exclusive entities that merely interact. However, ecological psychology and enactivism emphasize a dynamic relationship between organisms and their surroundings. While these approaches highlight how the environment influences perception and action, less attention is paid to changes in the organism-environment relationship that occur over longer timescales. Consequently, it has difficulties thematizing the shared practical context vital to skilled activity in professional, academic, and clinical settings, as well as in everyday life.

My project adopts a systems perspective that aims to push the insights of ecological psychology by proposing a more integrated view of the environment's role in shaping human behavior. This perspective conceptualizes the organism-environment relationship as part of an evolving meshwork of interactions among people and things, where structures emerge and transform over multiple timescales. In this view, organisms and environments engage in open-ended activities, continually redefining their boundaries and resulting in coordinated patterns of shared practice. These practices form the immediate and evolving context for individual actions.

Adopting this frame reveals new phenomena previously obscured, such as behavior settings. In my talk, I will present findings from fieldwork, which explores how participants within the REPAIRS consortium navigate and sustain their shared practical contexts across different timescales. This presentation will highlight the methodological, conceptual, and practical benefits of the systems perspective, demonstrating how it can bring the context back to life and bring it back to the forefront of cognitive science.

Oral presentations

Invited speakers

Ecological Psychology

Perception-Action Coupling in Collective Dynamics

William H. Warren

Department of Cognitive and Psychological Sciences, Brown University, Providence, RI, USA

What do we mean by the “perception-action coupling”? In the behavioral dynamics framework, interactions between the agent and the environment both generate and are regulated by perceptual information, and self-organized behavior emerges from the dynamics of this interaction. This basic picture has recently been extended inward to neural dynamics, and outward to collective dynamics. In this talk I describe our research on the collective dynamics of human ‘flocking’: the emergence of collective motion in human crowds from local pedestrian interactions.

How do local interactions give rise to collective behavior? What is the mechanism of self-organization? While most models of collective motion assume omniscient knowledge and rely on metaphorical social forces, we show that it is rooted in the perception-action coupling. Using VR experiments with virtual crowds, we first decipher the rules of engagement that characterize local pedestrian interactions, and the neighborhood of interaction over which they operate. We then identify and test the visual information that governs these interactions. Finally, using multi-agent simulations, we find that this visual model generates self-organized collective motion and reproduces data from real human 'swarms’.

The results show that putative social forces reduce to the perception-action coupling, and that the neighborhood of interaction follows from the laws of optics. Averaging within this visual neighborhood provides a positive feedback that serves as the mechanism of self-organization. Moreover, collective decisions such as a crowd splitting into two groups can be characterized as bifurcations in the collective dynamics, and are explained by individuals ignoring highly discrepant neighbors. In sum, collective behavior can be understood as emerging from the dynamics of the perception-action coupling.

How moving in unison can enhance social interaction in physical and digital realities.

Benoît Bardy
EuroMov Digital Health in Motion, University of Montpellier, France

Synchronization in space and/or time is a prevalent cooperative behavior in human every aspect of our behavior and contributes to our sense of well-being. In this presentation, I will emphasize the informational nature of human synchronization and its significance in understanding how our movements in social contexts reveal our identities. Additionally, I will explore how mixed-reality environments can be utilized to enhance synchronization.

I will introduce the concept of the Individual Motor Signature (IMS), which reduces the interaction of multiple degrees of freedom at various levels of the human body to one low-dimensional variable. I will show how these signatures are influenced when interacting in a dyad or group by morphological and movement similarities, emotional qualities, and social competencies. I will also present our recently developed digital architecture that modulates IMS in real-tim interactions. Whether intentional or spontaneous, interpersonal synchrony affects e during social interactions with humans and artificial agents, demonstrating how this architecture can be used to improve the social benefits of synchronization in mixed-reality environments.

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Ecologically-Inspired Perception-Action Research: A Catalyst for a Rehabilitation Practice that Celebrates Movement Diversity

Paula L. Silva
Department of Psychology, University of Cincinnati, USA

While many physiotherapists understand that the experience of disability is deeply shaped by the interconnectedness of individual and environmental factors (both physical and social), our practices remain largely fragmented and focused on "normalizing" bodily structures and functions. In this talk, I will present findings from my own research in perception and action—grounded in an Ecological-Systems approach—that I believe can help bridge this notable knowledge-practice gap. I will explore how findings from this research can foster a physiotherapy practice that celebrates and supports the unique movement strategies individuals with disabilities use to create enabling conditions for themselves in a world often insensitive to their bodies and skill sets.

Ecological Psychology & Dynamical Systems and applications

Catching and throwing without vision: auditory-motor coordination in people with visual impairments

Matthew Rodger
School of Psychology, Queen's University Belfast, Northern Ireland, UK

Many perceptual-motor skills require movements to be coordinated with static and dynamic targets in the environment, such as throwing to a location or catching a moving object. While vision is traditionally studied as the main perceptual modality for achieving these tasks, auditory perception can also support coordinating action in sporting and developmental contexts. This presentation will describe and discuss experiments which investigated interception and throwing actions based on acoustically specified targets, involving children and adults with visual-impairments, as well as blind-folded sighted comparators. Results show that people are generally able to use acoustically specified targets to coordinate these different actions, albeit often with less accuracy than when visual information is accessible. Furthermore, differences in movement strategies between sighted and visually impaired participants suggest effects of long-term adaptation in coordinating movements with sound. These studies explore the extent to which auditory perception can support pick-up of action-relevant information in the absence of vision. They also highlight the need to explore different ways that the environment can be adjusted to support development of motor coordination in young people with sensory impairments.

Different strategies for coordinating action with auditory information about moving objects in the environment.

Learning & Affordances: an Ecological Dynamics approach

Ludovic Seifert
University of Rouen, Normandie, France

This talk presents learning and skilled behaviors according to Ecological dynamics approach and emphasizes the role of exploration in learning both in novices and expert athletes. We argue that learners must explore to learn and doing so they learn to explore effectively, which means that they attune to relevant information for actions, they make better decision notably by selecting or switching among mode of action, exhibiting functional equivalence (as they exploited degeneracy of perceptual-motor system), and finally they better calibrate their perception-action system. We will exemplify our talk in sports like swimming, climbing and biking.

A multidisciplinary perspective on stroke rehabilitation

Dennis Mottet
EuroMov Digital Health in Motion, University of Montpellier, France

Restoring effective perception-action coupling during upper limb movement is one of the key challenges in stroke rehabilitation. A key idea, both practical and theoretical, is the dictum "use it and improve it or lose it," which sums up the idea that rehabilitation must target a sufficient amount of use-dependent neuroplasticity, the cornerstone of relearning and improving function of the paretic upper limb. However, each patient has different constraints and impairments, which also vary over time after stroke, requiring an individualized therapeutic approach for faster and better sensorimotor recovery.
I will show how, in collaboration with movement, computer, and rehabilitation specialists, we developed functional measures of hand movement and brain activity, and examined them in relation to neuro-mechanical constraints after stroke, drawing on computational models, to propose new ideas for guiding therapists to better individualize the nature and dose of therapy after stroke.

Philosophical underpinning perception-action

What is this thing called environment? Gibson and his critics

Rob Withagen
Department of Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

Gibson was unique among psychologists in paying so much attention to the environment. One of his famous claims is that the environment human and nonhuman animals perceive and act in consists of affordances, possibilities for action. In this talk, I will discuss Gibson's conception of the environment, how it replaced the mechanistic conception of the world as matter in motion, but also how it has been criticized by several authors. Rather than taking a position myself, I would like to invite the audience to think about their points of critique. Do the arguments hold water? Do they imply that ecological psychologists need to rethink what the lived environment actually is?

Perception, action, and history

Erik Myin
Department of Philosophy, University of Antwerp, Belgium

Ecological psychology started with Gibson. But it didn't fall out of thin air. I want to draw attention to a prominent predecessor of ecological psychology: the philosopher Thomas Reid. In his 1785 Opus Magnus Essays on the Intellectual Powers of Man, he developed a view of perception with affinities to the ecological program. Reid rejects that perception is of internal mediators or proceeds by inferences from sensations. He proposes a positive theory of how we perceive because of regularities appearing in how organisms interact with their environments. He details how visual perception continually gets refined as perceivers become more skilled and knowledgeable.

Historical awareness is important for current theorizing for several reasons. First, showing the roots of ecological thinking goes against a tendency to situate it as 'alternative', 'radical' or even 'fringe'. Second, it can be inspirational. Though there are many commonalities between the thinking of Reid and Gibson, there are also divergences. For example, Reid was keen to point to limitations on what are a legitimate explanatory aims for perceptual science. Though his views were constrained by the absence of the idea of biological evolution, some of his considerations might still be seen as positing questions about the scope of ecological theory. I will discuss the issue of whether perceptual science can prove that we are in direct contact with the world by citing lawful processes. I will argue that invoking history as what glues perceivers to what's perceived is a better, and more Reidian option, than pointing at laws.

Rehabilitation, Movement Science and Technology

NeuroMechanics of Human Movement and Neural Interfacing: A Spinal Motoneuron-Centric View

Dario Farina

Department of Bioengineering, Imperial College London, London, United Kingdom

One of the main limitations in the study of human movement is our poor ability to record in vivo from a sufficiently large number of neural cells to understand population behaviours and to associate a functional meaning to the cellular mechanisms that ultimately determine a movement. This limitation, which has a direct impact in technologies for human interfacing, can now be partly overcome, at least at the last stage of neural processing of movement, that is at the level of alpha spinal motor neurons. Motor neurons receive synaptic inputs from the entire neuromuscular system and they convert it into the neural drive to muscles. The spiking activity of motor neurons can be identified from recordings of electrical activity of muscles using either wearable (non-invasive) or minimally invasive sensors. Using these technologies, motor neurons are the only neural cells whose individual activities can be studied in humans during natural behaviour, without the need for neural implants. The talk will overview the technologies for motor neuron interfacing and their use in the study of neural control of movement and in the development of new assistive technologies.

Co-adaptation of assistive technology: taking the human in the loop

Han Houdijk

Department of Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

Assistive technology is an important intervention for people with lower limb impairments to regain walking ability. Many devices, ranging from adapted shoes and orthosis (that support the lower limb) to prosthesis (that replace the lower limb), are available in current rehabilitation practice. Technological developments aim to optimize these devices such that functioning is completely restored. However, despite the technological advancements of recent years success of these devices remains behind expectations. A potential explanation for this lack of success might be found in the complexity of tuning these assistive devices to the individual user. With the increasing technology, the number of device parameters that can be tuned has increase. Due to the large heterogeneity in user's anatomical and physiological properties, no one-size fits all parameter setting exists. Moreover, humans are, unlike the mechatronic assistive devices, no determined systems. Each user response differently to a given parameter setting and this response can likely change over time due to motor adaptation.

In current rehabilitation practice, tuning an assistive device to the user is a subjective, trial and error process. The complexity of finding individualized optimal settings for assistive devices can impede their effectiveness. In recent years, the paradigm of Human-in-the-Loop Optimization (HiLO) has been proposed to solve this issue. Human-in-the-Loop Optimization includes the user in the physical loop of an artificial intelligence-based optimization approach. A relevant set of tuning parameters of an assistive device are systematically manipulated based on a directly measured objective criteria (cost function). An artificial intelligence-based optimizer, iteratively proposes new settings until the

optimization criteria is reached. In this way optimal settings can be found, while taking into account behaviour (changes) of the user.
In this presentation, the Human-in-the-Loop Optimization paradigm will be presented and recent research results on the individualized optimization of footwear and lower limb prosthesis will be discussed.

Translation to rehabilitation from an industry perspective

Rehabilitation technology to improve gait & balance – from research to clinical practice

Frans Steenbrink
Motek Medical, Amsterdam, the Netherlands

In this lecture the state-of-the-art of currently available technology for gait and balance rehabilitation will be presented. More specifically, there will be a strong focus on real-time visual feedback, gait adaptability, and gait perturbations for human movement research and clinical rehabilitation. Real-time visual feedback can help to train on specific gait impairments to regain a normal gait pattern. For example, elderly can be given visual feedback on their propulsive ground reaction force to improve push-off. Although visual feedback can aid retraining of regular gait, we believe that everyday walking is more than just setting one foot in front of the other. It also requires the ability to adjust your walking pattern to different situations and to react to unexpected perturbations. For example, you may need to lift your leg up higher to avoid tripping over a loose tile, slow down to avoid bumping into someone, or recover balance after a slip. Training gait adaptability and recovering from perturbations may therefore be essential elements of gait rehabilitation.

Augmented-reality technology translated to real-world therapy through public-private partnerships

Melvyn Roerdink
Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands

Augmented-reality (AR) technology can be used to enrich rehabilitation with task- and context-specific content, enabling incorporation of variability, feedback and guided exploration in therapeutic motor-(re)learning processes. I am inventor of the patented world's first AR rehabilitation treadmill C-Mill (DIH/Motek/Hocoma) and of wearable AR technology applications for remotely prescribed and monitored gait-and-balance physical therapy in neurorehabilitation (i.e., Reality DTx by Strolll) and navigational AR cueing for gait assistance in Parkinson's disease (EIC Accelerator project NavigAIt with Strolll). In this presentation, I will discuss my learnings in translating scientific insights and academic AR prototypes into such commercially available AR treatment solutions used on a daily basis in rehabilitation and research across the globe.

Bridging science and commerce

Jasper den Boer
Umaco BV, Groningen, the Netherlands

To be able to continue developing new products as a company, it is important to ensure that it does not take too long for new developments to recoup their investments. A frequently asked question in the context of these developments is: What exactly is the minimum viable product (MVP)? A curious scientist wants to learn and discover as much as possible. To develop a home training aid for people who have had a stroke, which allows them to train their arm movements, a scientist will likely start with many motion sensors. How do you bring these two different worlds together?

Translation in perception and in action

From basic science to clinical applications in motor control research

Claudia Voelcker-Rehage
Department of Neuromotor Behavior and Exercise, Institute of Sport and Exercise Sciences, University of Münster, Münster, Germany

During my talk I will introduce our recently launched MSCA Doctoral Network TReND "Translational Research Network in Motor Disorder Rehabilitation: Advancing Understanding of Variability in Motor Control and Learning to Improve Clinical Practice". The overall goal of TReND is to systematically translate recent theoretical and methodological advances in motor control and learning research into clinical practice to improve clinical diagnosis and motor rehabilitation. Specifically, we will investigate the functional role of variability in sensorimotor coordination dynamics at the behavioral and neurophysiological levels in motor and mental disorders such as stroke, Parkinson's or Alzheimer's disease. I will illustrate the goal of TReND by presenting own projects on motor control and learning in fine motor tasks in older adults and on gait freezing in Parkinson's disease.

Quantifying the individual in motor sequence learning: Using multimodal data to enhance theoretical understanding.

Russell Chan
University of Twente, the Netherlands

In motor learning across health and disease, the holy grail is to correctly quantify individual performance and then augment for learning gains. Although theoretical frameworks provide the foundation, unique individual phenomena are often masked, but essential to provide idiosyncratic training. In this talk, I'll firstly outline my work to progress the experimental work in motor sequence learning by moving from finger-based tasks to whole-body learning combined with mobile multimodal technologies. Next, I focus on the quantification of individualised human motor learning in both the brain and body, and finally outline a short outlook of applications on the horizon. I hope that my views can be one of the many solutions the future requires to tackle the hard problem of individualisation in motor learning.

Implementation and effectiveness of rehabilitation technology

Effect of using a grip-supporting glove as assistive device with ADL: the promise of soft-robotics?

Gerdienke Prange
Roessingh Research and Development, Enschede, the Netherlands

In recent years, soft-robotics has gained interest as a possible alternative for rigid exoskeletons in support of walking for people with movement disorders or bending and reaching tasks for workers, for instance. A soft device has substantial advantages for usability and safety, which shows promise for future use of robotics in clinical settings. One of the few soft-robotic devices on the market nowadays is a soft-robotic glove, Carbonhand (Bioservo, Sweden), that supports hand grip. It is fully wearable, can be worn for hours on end and can be used unsupervised in people's homes. This makes it highly suitable to investigate its potential for a direct assistive effect, but also to assess whether their unsupported arm or hand function changes when people use such a robotic support during ADL for several weeks. We coordinated a clinical trial among 8 Dutch clinical centers, following 63 participants with hand function limitations during 6 weeks of using the soft-robotic glove and measuring changes in hand function over time. The results point to a very promising outcome, which might open up entirely new opportunities for rehabilitation and care in the future.

Add value and reduce waste in research: patient engagement and implementation

Corry van der Sluis
Department of Rehabilitation Medicine, University Medical Center Groningen, Groningen, the Netherlands

As researchers we pay much attention to the development of innovative technologies and how we can prove effectiveness of these innovations. We are good at writing grant proposals, designing diverse types of studies, recruiting participants, analysing data and presenting the results in a paper or at a conference. Many times the research activities are finished after presentation of the results. However, we design our new technologies or innovations for a target group, mostly patients. Indeed, patients are involved, but mostly as participants and not as partners in the research. If they act as partners, value can be added to the research, research waste will be reduced, since results will become more relevant, and more attention will be paid to the implementation of results. Implementation is not a simple next step after publication of research results. On the contrary, a specific strategy to implement results is required from the beginning of the project. In this presentation the focus will be on how to include patients as partners in research and how to implement research results. Upper limb prosthetics will be used as an exemplary case.

Poster presentations (in alphabetical order)

Socioeconomic Benefits of Medical Rehabilitation

Chiara Basaglia, Laura Golenia, Thomas Preuss
MEDIAN Unternehmensgruppe, Germany

Rehabilitation has significant socioeconomic implications, influencing individuals' productivity, quality of life, and social participation. Inpatient rehabilitation market is growing due to aging of population, increased morbidity due to medical advances and extended work life. However, rehabilitation often lacks adequate acknowledgement as a fundamental pillar of the healthcare system. The aim of the project is to provide concrete evidence of the economic and social value of rehabilitation in Germany. By analysing data from MEDIAN's rehabilitation and follow-up care services, I aim to quantify the benefits of rehabilitation in terms of return to work, improved quality of life, reduced social isolation, and enhanced self-sufficiency in daily activities.
The patients considered in this analysis are from the orthopedic, pulmonology, and cardiology departments. I examined various aspects of the Work Ability Score (WAS), a Patient-Reported Outcome Measure (PROM) that evaluates worker productivity. Additionally, I constructed a Bayesian model to explore the associations between WAS and specific patient data, which could play a crucial role in improving or worsening patients' work ability. For this last analysis the patients were divided based on gender.
I started evaluating other PROMs for the different departments. These include the Pain Scale, which is used for assessing the patient´s pain severity, the Oswestry Disability Index (ODI), which measures permanent functional disability for those with lower back pain, and the Hannover Back (FFb-H-R), assessing the severity and impact of back pain on daily life. Moreover, I utilized the VR-12, a self-assessment questionnaire that measures health-related quality of life, taking into account both physical and mental health, and a standardized Patient Satisfaction Questionnaire filled by patients after the rehabilitation, defined by payor.

The effects of practice conditions on task performance while using the sensory substitution glove

Saroosh Bilal[1], Raoul M. Bongers[2], David M. Jacobs[1]

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Efficacy of skill acquisition is impacted by the practice conditions. This study investigated the effectiveness of practicing a reaching and grasping task with a sensory substitution glove (SSG) while using variability of practice paradigm. The distance-based SSG provided vibrotactile information on thumb or index finger if the thumb or index finger pointed towards the object. We used a pretest-training-post-test design, recruited forty-four participants, and divided participants into two equally sized groups with the same pretests and post-tests. One group trained with constant task conditions, facing the same initial and target object locations and sizes on every trial. The other group trained with variable task conditions, encountering different initial and target object positions and sizes on different trials. Results demonstrated improvements in task performance for the variable group in both the constant and variable post-tests. The constant group, however, only showed an improvement of performance in the constant post-test. Additionally, we observed increased exploration and better information detection after practicing task for both conditions. Various strategies to perform the task were identified, highlighting individual differences. In conclusion, our study suggests that incorporating variability in training programs supports skill acquisition, although exploration and information detection improve after both types of practice.

Estimating the time structure of descending activation in fast reaching movements via optimal control

Lukas Bildheim, Rebecca Baldi, Lei Zhang, Gregor Schöner
Institut für Neuroinformatik, Ruhr-Universität Bochum, Germany

Using a optimal control of a muscle model we find the time courses of muscle activations necessary for a simplified biomechanical model of a planar arm with six muscles to reproduce experimentally observed reaching movements at two speeds. These muscle activations are then used to analytically invert a stretch reflex circuit model to find the descending activation that would drive this movement. We find the temporal structure of these descending activations to substantially differ in shape between speed conditions, reflecting the need to anticipate delays in the model as well as stronger interaction torques at higher velocities. We further see the influence of the stretch reflex on the fundamental nature of the signals.

Self-Organizing Maps for the Estimation of Risk of Falling from a Pelvis-Mounted Accelerometer

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Assessing the risk of falling in the elderly population is of paramount importance due to the severe consequences associated with falls. Furthermore, novel machine learning algorithms such as Self-Organizing Maps (SOM) can offer unprecedented advantages over traditional assessment methods of risk of falling due to their ability to handle complex, high-dimensional data and being completely unbiased. This study employs SOM to evaluate the risk of falling from a pelvis-mounted accelerometer in two groups of older adults who underwent an 8-week training protocol on a treadmill. The control group experienced strong perturbations during their training whereas the control group did not. The two groups were screened for recent falls occurred in the 6 months prior to the beginning of the study (baseline) and 6 months after the end of the study (post-intervention). As a result of the training, participants in the experimental group significantly reduced their falls in the post-intervention period compared to the control group. However, traditional gait analysis metrics failed to detect any significant changes between the two groups. Therefore, this study aims to use SOM to detect differences between the two populations that were left undetected by traditional biomechanical means. These insights can inform the development of targeted intervention strategies that incorporate perturbation training to reduce fall risk among older adults. Furthermore, this study highlights the effectiveness of SOM in handling complex health data, providing a deeper understanding of fall risk factors and enhancing preventive measures for the elderly.

A nonlinear dynamical model of the angle-of-approach effect in manual lateral interception

Danial Borooghani[1], Remy Casanova[1], Frank T.J.M. Zaal[2], Reinoud J. Bootsma[1]

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It has been demonstrated that the control of manual lateral interception tasks has a prospective rather than predictive nature. This matter manifests itself prominently in the systematically different kinematics of hand movement for targets moving uniformly and arriving at the same interception position with the same flight duration time while starting to move from different points. This phenomenon is the angle-of-approach effect (Ledouit et al., 2013) and suggests that both ball position and ball velocity affect the motor control of the hand movement toward the future interception point. For the purpose of modelling this movement, since the existing linear dynamical models could not adequately capture the empirically observed hand kinematics, an information-driven nonlinear dynamical model is developed. Combining conservative Duffing stiffness with both Rayleigh and Van der Pol nonconservative terms allowed the generating of discrete movements with the required kinematic characteristics. Visual guidance was incorporated by (i) the (perceptually specified) current interception location aimed for and (ii) scaling the model parameters to the (perceptually specified) time-to-contact of the target with the interception axis. The former, as a stand-in based on a combination of current ball position and velocity, evolves over time and thereby results in the emergence of the angle-of-approach effect. The model could adequately capture a dataset of empirically observed hand kinematics incorporating 28 different target trajectories under four different ball velocity (and hence time pressure) conditions. We conclude that information-movement coupling in the form of a principled information-driven nonlinear dynamics-based model with as few as six coefficients can adequately capture the richness of behaviour observed in manual lateral interception tasks.

Practice Effects and Movement Kinematics in a Reaching Tasks: Geometric vs. Dynamic Affordances

Giacomo Bressanello, Naomi A. Schreurs, Raoul M. Bongers, Joanne Smith
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Affordances are the opportunities the environment affords for action and can be perceived. Research has shown that with practice, affordance perception becomes more accurate. However, this learning by doing, might differ for affordances where only body geometrics are relevant compared to where also action dynamics are important. Therefore, this study aims to identify the learning patterns found in movement kinematics in the reaching task. Examining Movement time and velocity patterns of the task we will aim to discover the different effects of practice. Participants were divided into two groups: arm-only reach vs arm-and-torso reach. Participants were asked to estimate their maximum reachable distance towards a cup (perception) and then reach and grasp the cup (action). The location of the cup was adjusted using a pulley system and end-effector kinematics were recorded. A pre-test, two-block practice phase and post-test design was used. Results of the kinematics analysis showed that there is difference between the two groups. We compared movement time between 1st practice trial and last practice trial for both groups and showed that movement times only differed in the arm-only group ($p=0.031$), with longer movement times in the 1st trial of practice.
Furthermore, more and different kinematics analysis of the reaching actions will be examined to determine whether during practice people learn and explore different affordances.

A method for uncontrolled manifold analysis of muscle activation patterns producing joint torques

Wanxiong Cai, Lei Zhang, Gregor Schöner

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Skeletal muscles are believed to function as groups, i.e., muscle synergies, to produce movements. These synergies given by applying matrix factorization to electromyography (EMG) data help understand motor control by grouping muscles into fewer motor modules. Still, such fixed sharing patterns alone don't explain this redundancy. Studies at the joint level have shown that redundancy is crucial for achieving stable end-effector outcomes through the coordination of joints characterized by uncontrolled manifolds (UCM) in joint space. We are inspired to investigate if similar coordination exists between muscles during arm movements. A planar arm reaching task is used where participants keep the wrist, elbow, and shoulder joints in a horizontal plane and move their hands from starting locations to target locations displayed on a screen. Because the biomechanical model of joint torque production is too complex for UCM analysis, we build a linear model with a simplified hill-type muscle-force model. Joint torques are computed by inverse dynamics and regressed on EMG. The Jacobian matrix of this model is constructed of coefficients given by linear regression with the muscle-force model. Our results suggest that this model's performance is acceptable on several participants' data. It's plausible to use this method to investigate if UCM effects exist on muscle activation patterns producing joint torques.

Learning trajectories in informational spaces: new insights for our ACL rehabilitation game based on coordination

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The effects of our joint-action game on postural stability and coordination were inspected in the context of the programme REPAIRS "RE-learning Perception-Action in Rehabilitation from a Systems perspective". As mentioned in the oral presentation, our game designed from a systems perspective led to the emergence of synergies and postural changes that should be beneficial for ACL rehabilitation. Whereas the secondment in clinics (R'Equilibri_us) gave us the opportunity to better understand the dialogue between research and clinical areas, the academic secondment (UAM) was fruitful to investigate the learning aspects intrinsic to REPAIRS. This third and last investigation of the PhD project aims to explore the relationships between informational and movement variables in our ball-and-board task over practice.

Using the direct learning approach, the first step was to observe that performance gradually improved over practice. The second step was to identify which movement variables should be controlled to successfully perform the task. Torques applied in the ball direction and in the perpendicular direction were defined as movement variables. As a third step, we investigated the relevance of 18 candidate informational variables for motor control. Correlation analyses between these candidate variables and the applied torques guided us to select 3 relevant informational variables for the control of the torques in both directions. The fourth step was to understand how the dyads explored the usefulness of the available information over practice by representing their learning trajectories in two informational spaces related to the two torques. Finally, correlations between dyads' performance and coordinates in each informational space highlighted that the dyads with higher performance used more information related to the task goal (target) compared to the dyads with lower performance at the end of the experiment. The present methodology could be useful to study re-learning in ACL patients.

Can we perceive for another? Affordance of interceptability for others considered

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We previously demonstrated that individuals can make accurate judgments about their own abilities to intercept a moving target (a virtual ball) using a hand-held slider that controls an on-screen paddle (Damle et al., 2024). If people can indeed perceive their own affordance of interceptability, we asked the relevant and related question of whether this also extends to perceiving the abilities of others. Using the same manual lateral interception paradigm, we recreated the movement kinematics of an actor, which we presented to participants. We tested participants' ability to make perceptual judgments of interceptability for this actor. We hypothesized that individuals would be able to perceive this affordance for the actor. We also manipulated two further aspects of the task, namely, the role of prior training and of occluded-vision of the screen. Three groups of 12 participants each were administered a judging session, wherein they made verbal perceptual judgments about the interceptability of a ball for the actor. Two groups (G1 and G3) also received prior training on the interception task itself. Two groups (G1 and G2) received full-vision of the ball-and-paddle kinematics, whereas one group (G3) received late-occluded-vision. We recorded the verbal judgments made by the participants and found that they were able to make fairly accurate perceptual judgments about the actor's interceptability. A linear mixed model analysis revealed that the variables that determined perceived interceptability for another (actor) were identical to the variables that guide interceptability for oneself. This implicates that individuals can perceive the affordance for another individual analogously to the way they do for themselves. Surprisingly, prior training did not significantly influence the participants' perceptual judgments. Likewise, there were no significant effects of occluded vision on the perceived interceptability, only on the timing of verbal-calls. Overall, these findings contribute greatly to the sparse work on affordances for others.

Temporalizing Behavior Settings

Giulia Di Rienzo
University of Antwerp, Belgium

Recent research in ecological psychology has re-examined Behavior Setting Theory, developed by Roger Barker in the 1960s, to address the social aspects of perception. Barker's work suggested that the environment could be described as composed of larger-scale ecological units - behavior settings - which predictably influence human actions. A concrete example of a behavior setting could be the dynamics within a classroom during a philosophical psychology class or a coffee shop operating from 7:30 am to 7:00 pm.

While Behavior Setting Theory offers a practical empirical framework for understanding the social and material ecology of the human environment, researchers such as Alan Wicker and Harry Heft have pointed out its limitations. One criticism is the theory's tendency to depict behavior settings as stable and a-temporal units. They argue that behavior settings should be understood as developing and emerging in time.

This poster aims to reframe behavior settings as processes that are performed over time rather than predetermined entities. We make use of the concept of temporal reciprocity, which suggests that the interactions within a behavior setting are transactional and continually shape both the setting and its elements. This idea aligns with Dewey and Bentley's notion of "transaction," where being is seen as a process of becoming.

Ontological characteristics of behavior settings, their stability, and boundedness are thus not predetermined or unfolding in specific pre-planned phases of their development; they emerge and gain determinacy through ongoing activities and interactions with the world. By temporalizing behavior settings, this approach highlights their nature of becoming and proposes that they could hold a middle ground between the (inter)personal and large-scale communal processes in which we live.

Probing other's Presence: Probabilistic Inference Across Brain Scales Reveals Enhanced Excitatory Synaptic Efficacy

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The mere presence of others is integral to social cognition and is a major modulator of task performance. However, the mechanisms through which mere presence exerts such modulations on behavior remain poorly understood. This study bridges this gap by examining how mere presence of others alters synaptic efficacy across three spatio-temporal brain scales in subject groups comprising of Monkeys and Humans. Monkeys performing a cognitive task exhibited increased activity in brain regions associated with attention. Similarly, the female subject group in Humans displayed improved task performance during the presence condition, which was subsequently linked to increased synaptic efficacy within Dorsal and Ventral attention networks. We propose that this attentional modulation via distractor suppression is driven by enhanced effective connectivity between attentional brain regions/networks. Our findings provide a novel neurobiological framework for mere presence effects and their potential implication in social neuropathologies such as Autism Spectrum Disorder or Schizophrenia.

From independent individual to interdependent team: solo-to-joint transfer in a manual ball-and-beam task

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Many daily life activities require interpersonal coordination (IPC). According to the ecological-dynamical approach, IPC has a synergistic structure across individuals. Not much is known, however, about the acquisition process that leads to such coordinative structures. To address this issue, we employed the manual ball-and-beam task, a challenging perceptuomotor task in which agents have to roll a ball as fast and accurately as possible between two targets on a long, hand-held beam. Since this task can be performed individually as well as dyadically, it allowed us to assess how joint performances arise from individual performances. 16 participants first practiced the task individually over two days, with 18 two-minute trials per day. Subsequently, all participants were paired into dyads, with high performers (i.e., more target hits) being paired with low performers. The 8 dyads jointly performed the ball-and-beam task for another 18 trials of practice. Using this design, we determined to solo-to-joint transfer of six pertinent indicators of performance through a linear regression analysis of the dyad's joint performances with the sum of the individual's solo performances. Results demonstrated that not only the dyads' number of target hits, but also the frequency and timing of their jointly enacted beam movements could be well predicted from the corresponding solo performances. Moreover, we found asymmetries in the interpersonal coordination, in the form of leader-follower dynamics. High performers were more likely to take the lead than low performers, although leadership was not proportionally related to the differences in the solo performances. We concluded that who interacts with whom is relevant to the outcome as well as the underlying interpersonal coordination of a joint activity.

Antagonistic coupling and lead-lag patterns in top-level between-agent coordination

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Previous research on interpersonal movement coordination in lab experiments as well as in sport settings inferred tendencies of dyads (or two teams) to synchronize towards in-phase and antiphase coordination. Mathematically, these two coordination patterns emerge merely because coupling is formulated in such a way that cause attraction of both oscillators towards each other's behavior. Particularly relevant for sports, implementing 'antagonistic' coupling between the model oscillators (i.e., one oscillator attracts while the other repels) reflects 'conflict of intention' in the interaction (cf. defender-attacker coupling), and yields novel predictions that contrast to the canonical in- and antiphase attraction. The present study illustrates this alongside data of tennis dyads. We examined the relative phase of lateral movements of players in singles tennis, digitized from broadcasted footage of 40 selected long baseline rallies (i.e., >9 strokes) of top 20 matches in ATP tournaments. In accordance with expectations from antagonistically coupled oscillator dynamics, results showed prevailing occurrence of episodes around |90|° lead-lag phase relations. Notably, these patterns could not be systematically ascribed to detuning between the two opponents' lateral displacements. Hence, the observed lead-lag patterns could indeed be predominantly attributed to the antagonistic interaction as such. Together, this demonstrates the expedience of incorporating repulsive coupling between oscillators to study interpersonal dynamics for relevant interactive scenarios.

Impact of Object Weight and Participant Age on the Dynamics of Human-to-Human Object Handovers

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Accurate anticipatory knowledge of objects weight might facilitate human-to-human handover actions as this information can inform response-planning by the receiver. It is already known that older participants scale their grip forces less accurately to the objects weight than young adults. Our aims were, thus, to investigate I.) whether receivers can anticipate the weight of an object from observing the giver's kinematics and II.) whether there is a difference between young and old adults.

Twenty dyads of healthy young (22.6 ± 2.5 years) and 20 dyads of healthy old participants (82.5 ± 2.6 years) completed the experiment. A motion capture system, as well as a self-constructed test object for grip force measurement were used to record the kinematics and grip forces. Two different object sizes (small, big) and three different object weights (light, medium, heavy) were used. Participants had no knowledge about the object weight before each trial.

Givers lift delay/ maximum wrist velocity was significantly longer/lower for heavier objects than for lighter objects. Thus, observable information about the object weight was available. No differences were found in givers peak grip force rate between the object weights. However, the ANOVA revealed higher receiver peak grip force rates for heavier objects. This indicates correct estimation of object weight class. Since receivers seem to be able to anticipate the object weight, but givers cannot, we assume that receivers have information that givers have not. We argue that receivers use givers kinematics to estimate the object weight. There is a difference between young and old participants in that older participants do not only seem to use the giver kinematics as a weight cue, but also the object size. We suggest that older persons rely to a greater extent on visual object properties in their everyday lives and therefore, object size influences weight anticipation.

Intra-Trial Search in Joint Space during Learning a New Coordination Pattern

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Learning novel motor skills require search for preferred movement coordination patterns to accurately perform the task. Existing literature quantifies search as systematic changes in task space or performance variables at the end of trials during learning. However, search process might also operate at a shorter timescale and might be prevalent even as the movement is ongoing, i.e. before the goal is reached. In this study, intra-trial search is characterized by the change in amount and structure of variability in the joint space within a trial across the training phase. This study aims to identify the influence of imposed and inherent movement variability on intra-trial search. In a previous study we demonstrated that imposed variability results in increased search behaviour at the end of trial and found limited effect of inherent variability. Since inherent variability is the flexibility in movements of an individual when performing a task, it is expected that inherent variability would influence intra-trial search. The hypothesis is that high inherent variability results in increased intra-trial search, accelerating acquisition of new coordination patterns. Firstly, participants are categorized according to their inherent variability based on their task-irrelevant variability in performing a reaching task with occasional target jumps. This was followed by a virtual lateral interception task with a manipulation on imposed variability i.e. blocked and random practice groups. A redundant mapping was introduced between the upper limb joint angles and the virtual paddle position such that the participants had to learn a new joint angle coordination pattern to accurately control the paddle for interception. The amount of intra-trial search will be quantified as the pathlength of the trajectory in joint space for each trial. The structure of the search and formation of coordination patterns will be assessed based on task-relevant and task-irrelevant variability at each time step within the trial.

Is it an obstacle or simply an object? The use of proactive gaze allocation during route selection through dynamic environments

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People show proactive effort to gather task-relevant visual information in a variety of tasks. How people learn the distinction between task-relevant information and information irrelevant to their task in dynamic, unpredictable environments is unclear. Uncertainty also remains about how people use their gaze allocation when action choices must be made. To better understand this, we designed a route selection task through an environment filled with three types of virtual objects. Each type of object had a colour that coded a specific movement behaviour. Objects of one colour always formed an obstruction to the path of the participant, thus holding task-relevant information. The other objects either moved away from the participant or did not move at all, thus being non-informative for the task. Through repetitive exposure to these objects and their colour-coded behaviours, we investigated whether people can learn to create expectations about the objects' behaviour and use these expectations to allocate gaze to task-informative objects. The results showed that, over time, fixations on task-relevant objects did not differ from fixations on objects irrelevant to the task. This implies that participants did not allocate their gaze based on learned expectations about environmental objects. Interestingly, participants spent most of their time fixating on the path between objects. This suggests a different use of visual information for route selection. Rather than using visual information about objects' locations to avoid them, people fixate on locations that allow obstacle-free travel to ensure proper foot placement and anticipate curves on the future route.

Rocking against each other: Dynamics of between-agent interactional opposition

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Between-agent interaction is often of collaborative nature, but can also involve conflict or opposition, such as competitive sports situations (e.g., attacker-defender) and conflicting social (movement) interactions. In contrast to common attractive (cf. cooperative) coupling, this entails repulsive-attractive coupling (cf. 'attacker-defender'). Modelling two coupled oscillators with such antagonistic interaction yields dynamics that deviate from canonical synergetic dynamics. For example, while cooperative coupling entails attraction towards 0° phase relation (in-phase) and/or 180° phase relation (antiphase), antagonistic coupling settings yield repulsion from in- and antiphase. For settings close to symmetric antagonistic interaction, this can in fact entail convergence towards phase relations around 90° and/or -90°.

Here we present empirical results from an experiment in which pairs of participants coordinated in rocking chairs in both cooperative and antagonistic settings. In the latter, one participant was instructed to move in-phase with the partner (reflecting attractive coupling) while the other was instructed to achieve an antiphase pattern (reflecting repulsive coupling). For the antagonistic trials, relative phase values indeed accumulated between 0°-100° or -100°-0°, depending on which dyad-member was instructed to achieve antiphase. Furthermore, interactive opposition appeared to boost amplitude and frequency of the rocking movement altogether. Notably, the antagonistic trials comprised a variety of behaviours, dominated by frequent changes between different coordinative patterns, obviously yielding much higher pattern variability compared to the cooperative trials. All this shows the unique behaviour that dyads express when coupled in opposition, highlighting the necessity to study and conceptualize such situations distinctively from cooperative scenarios.

Moving larger to (re-)stabilize coordination

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Coordinated movement prevails by virtue of interaction between embedded motor processes. Modelling coordinated body parts as two coupled oscillators, yields coordination patterns that attracts towards 0° phase relation (in-phase, synchrony) and/or 180° phase relation (antiphase, alternation). In this context, effects of movement frequency are canonical. Formally, however, the coupling forces and, thus, coordinative stability are mainly a function of the *amplitudes* of the oscillations. As such, enlarged movement amplitudes stabilize coordination and may help to (re-)learn to coordinate movements. This notion is more so appealing because manipulating movement amplitude would be exceedingly straightforward and utile for (therapeutic) training purposes. However, surprisingly few interlimb coordination studies have considered amplitude in their analyses. Arguably the most pertinent exception was a study that was specifically designed to tear apart effects of frequency and amplitude (Post et al., 2000). Unfortunately that experiment had 6 participants only, mainly because the most challenging conditions (antiphase at high frequency and large amplitude) could only be performed by few. With an aim for generalization, we therefore performed a replication experiment with some design simplifications, in which 26 participants oscillated their lower arms around the elbows in 1) in-phase and antiphase mode, 2) at prescribed frequencies of 1, 1.25, 1.5, and 1.75 Hz, and 3) at 0.1, 0.2, and 0.3 rad prescribed amplitudes. Overall, while coordinative measures indicated lower stability for higher movement frequency, coordination indeed enhanced for larger amplitudes. Contrary to more recent indications (De Poel et al., 2020), these effects seemed largely additive. Together this generalizes that larger movement amplitudes can stabilize coordination.

Performance and Kinematics of Interceptive Behavior for Catchable and Uncatchable Targets in Low and High Textured Environments

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Optic flow can be used to guide interceptive behavior (optic flow strategies) but is not needed to do so (egocentric direction strategies). In this study, we investigate how changes in optical patterning influence the performance and kinematics of interceptive behavior for catchable and uncatchable targets. To that end, we designed a Virtual Environment wherein participants were required to intercept moving targets using a connected ergometer bike. Two experiments were carried out. In the first experiment, the optical patterning of the virtual environment was varied such that there was no optical patterning; sparse optical patterning; or dense optical patterning. We recorded participant and target kinematics to study interceptive behavior. We analyzed the data using Generalized Additive Models. The results show that participants intercepted significantly more targets for denser grids. Furthermore, we found that participant paths were increasingly non-linear with decreasing grid density and that participants maintained a greater bearing angle to their target throughout. These findings indicate that interceptive behavior is more effective in conditions that allow for the use of optic flow strategies. In the second experiment, the optical patterning of the target was varied to either have no patterning (untextured ball) or intricate patterning (road bike). The results show that participants performed significantly better in the bike-condition than in the ball-condition. Participants kept a greater bearing angle for the ball-target than for the bike-target. No significant differences were found in the linearity of paths. These findings suggest that intricately textured targets provide more information for interception than untextured targets yet do not cause different interceptive strategies in participants. The results of this study show that optic flow strategies and egocentric direction strategies are not equivalent, either from a performance point of view (realization of affordances) nor from a kinematics point of view (interception paths).

Coordinative structures exploit co-activation and co-variation of muscles

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State of the art myoelectrically controlled hand prostheses use machine learning (ML) as the control algorithm. Patient reports and lab studies demonstrate that the use of an ML controlled prosthesis is not robust and difficult to learn, limiting functionality. These limitations might be related to requirements of consistent and specific muscle activations to control the prosthesis. To improve prosthetic control, and thus functionality, we examined properties of natural muscle activation in a myocontrol task, mimicking hand prosthesis control. Learning a new task entails learning a new coordinative structure organizing degrees of freedom, such as muscles. Within a coordinative structure, muscles co-activate to produce a desired movement of the end-effector but muscles also co-vary to stabilize this end-effector movement. The current study asked how co-activation and co-variation in coordinative structures developed in learning a new myocontrol task and whether the muscle activations are consistent over time. In this task, EMG activity of four muscles of the lower arm was mapped onto the movement of a ball on a screen in an intuitive manner. Each muscle moved the ball in another diagonal direction, but at least two muscles had to be co-activated to bring the ball on the target. Participants performed four sessions on consecutive days. Results showed that participants could learn the task. In all directions of virtual ball movement and in all phases of learning the ball was controlled with activation of all four muscles. This indicates that the coordinative structure exploited co-activation and co-variation concurrently in all phases of learning. Moreover, no consistency was found in the muscle activations throughout the training sessions. The implications of the results for the control of upper limb prosthetics will be discussed.