Neurocognition and Action

Biomechanics Group

Advisory center for

Intelligent Assistive Technologies:

- **Analysis of Mental Representations -** Software Licence
- **Adaptive Cognitive Training (ACT)-**Basic package & Software Licence
- **Adaptive and Mobile Action in Daily Living Activities (ADAMAAS)**
- **Personal Coach Chair**

Performance Diagnostics:

- **Measurement of Mental Representations**
- **Cognitive Diagnostics of Tactical Skills**
- **Cognitive Diagnostics of Technical Skills**
- **Cognitive Diagnostics for Teams**
- **Biomechanical Analysis**

Training & Optimization:

- **Regulatory Training**
- **Self-Instruction Training**
- **Mental Coach Education**
- **Mental Training**
- **Routine Training**

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Analysis of Mental Representations

The Neurocognition and Action (NCA) research group at Cognitive Interaction Technology- Excellence Center at the Bielefeld University, Germany, is analyzing human memory structures and applies these findings to the next generation of user-adaptive systems.
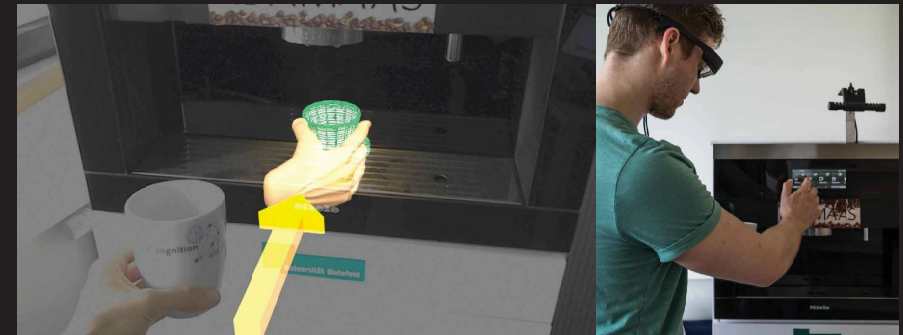
ADAMAAS: Intelligent glasses provide assistance for activities such as preparing coffee, baking a cake, repairing a bicycle or even practicing yoga

Mental representations in general play a central role in the control and organisation of actions. Regardless of whether a surgeon is selecting the appropriate instrument for an operation or a basketball player is deciding to pass a ball to a teammate, the performer must use a mental representation to sort through an exceptionally large amount of information. Frequently in sport, the action-relevant information is available only under extreme time pressure. Mental representations must be rapidly available and provide clear criteria for selecting the appropriate motor response required for skilled performance. Because rating and sorting methods do not allow a psychometric analysis of the representational structure, a methodical procedure called structural dimensional analysis of mental representation (SDA-M) is applied. The SDA-M contains a special split procedure involving a multiple sorting task, which creates a distance scaling among Basic Action Concepts (BACs) of a suitably predetermined set. Then it uses a hierarchical cluster analysis to transform the set of BACs into a hierarchical structure.

The relationship between mental representations and motor performance is not only an issue for basic research but also has implications for practical work with athletes, in the context of assistive technologies, or in applied fields. The NCA is an interdisciplinary research group which combines cognitive psychologists, linguists, biologists, sports and movement scientists, neuroscientists, computer scientists and engineers. The NCA has generated software tools for assessing long-term memory structures and predicting human errors for a given task. It can be used for tasks such as using specific high-tech machines, building birdhouses from wood, or doing exercises at home. The required data is gathered by a semi-automatized experimental measurement: Using a special app[1] created by the NCA group, users are asked to judge whether they think that different pairs of actions belong together during the task execution. Subsequently, the software calculates the person's memory structure for each task. Based on this structure, researchers assess about mental actions and potential action failures.

In Organizing Actions and Language Events
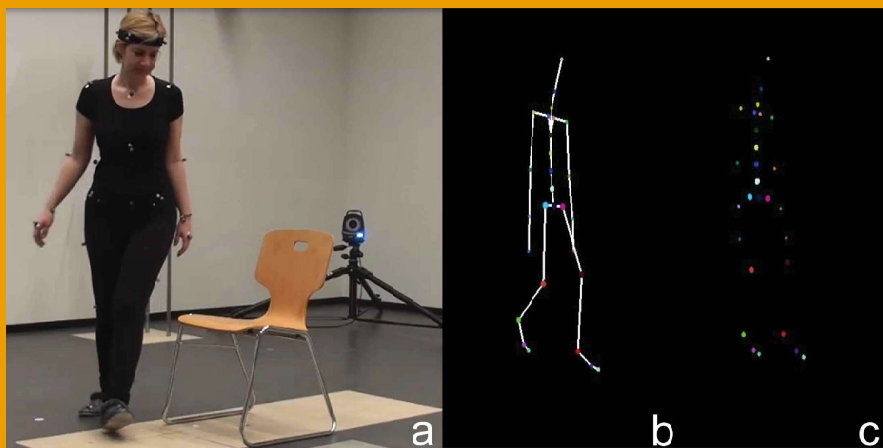
Action Event Discrimination and Sensorimotor Interlingua: (a) video while capturing actions that correspond to verbs (e.g. turn around, herumgehen) and their avatars (b. with bones, c. point). Apart from kinematics measurements, both videos and avatars were used for analysis of mental representations

The Analysis of Mental Representations is a powerful tool to perceptually ground language to action, which is an unsolved problem in both Human Robot Interaction research and Cognitive Science. The combined study of cognition through action, embodiment and language is a unique challenge. The idea is that a lot of issues concerning motor event conception and representation in combination with their labelling, possibly in different languages, could be better understood. The scope of the CITEC-Graduate School project "Action Event Discrimination and Sensorimotor Interlingua" is an event segmentation of a motion continuum through the isolation of the minimum elements that distinguish an action, to create a motion id for each individual. These separate motion events are named in different languages to form a sensorimotor interlingua. Labelling of sensorimotor data emerges as a necessity for robotics.

"The combined study of cognition through action, embodiment and language is a unique challenge."

NCA utilizes different research methodologies to ground language to action, such as (i) capturing motion data that correspond to motion verbs, (ii) analysing ERP and eye-tracking data to locate the critical moments that distinguish actions, and (iii) understanding the cognitive mechanism of categorizing motion events and verbs via analysing mental representations. Language somehow filters what we communicate and eventually expresses the filter that affects the way we perceive reality. However, our data has shown that in the case of verbs, native speakers categorize concepts based on the first lexical compound (preposition that reveals the path of the action), while in abstract actions performed by avatars, they emphasize on the second compound, which reveals manner of the action. In the concrete action condition (videos), the categorizations appear broader, because the basic mental categorizations of actions/verbs are further changed when environmental properties in the video, such as objects, interfere. Therefore, the analysis of mental representations suggests that favour some available perspectives of viewing events, rather than filtering perception.
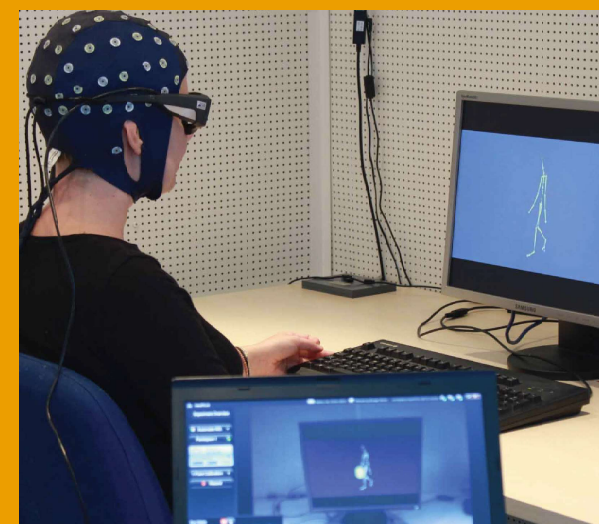

ERP and eyetracking analysis of verbs and avatars permit us to specify whether the action is understandable in an abstract environment and specify the critical moment and the important joint-ankles for the recognition
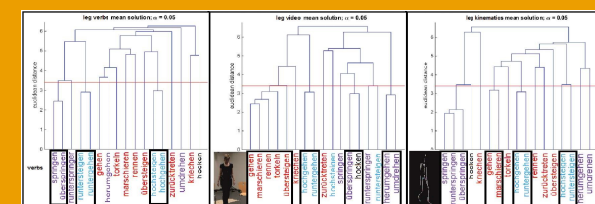
Structural Dimensional Analysis of Mental Representations between verbs, videos and abstract environment avatars. In black squares the statistically significant clusters

In Cognitive Task Assistance for the elderly and disabled
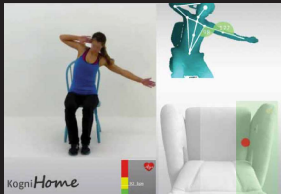
The Personal Trainer Chair prototype

## Adaptive Cognitive Training (ACT)

Based on our extensive previous research, we ascertain that mental representations play an important role in planning and executing complex actions and movements, especially for people with cognitive disabilities. Some may fail to conduct all relevant tasks to prepare a coffee machine, while others may mix-up specific sequential tasks during their daily work. In the joint project Adaptive Cognitive Training (ACT) between the NCA group and the von Bodelschwingh Foundation (Bethel) - one of the largest health care centres in Europe- we investigated the memory structure of different work-related tasks by deploying the Structural Dimensional Analysis of Mental Representation (SDA-M) and found significant differences between the instructors and the handicapped trainees. ACT uses this cognitive assessment to identify differences in the memory structure on an individual level. To support

the learning process, we developed an adaptive training terminal to analyse the cognitive structure automatically and provide an adaptive feedback. The terminal provides individualized training advices and helps to identify unstructured working tasks. Depending on the trainee, the training can include self-instruction training or imagery training. Furthermore, instructors use the terminal to address trainees in a more targeted way for earlier intervention. The regularly repeated cognitive diagnostic assessment makes changes and progress for the instructors and the trainees visible and enriches the learning progress.

Personal Trainer Chair

In the context of the KogniHome project, the Personal Trainer Chair (PTC) was

developed to support and motivate daily exercise of all family members in a smart-home environment. It is designed to be a ubiquitous interaction system: by combining mental diagnostics, marker-free motion tracking and natural interaction, the system seamlessly integrates into the living room. It provides a motivating and fun exercise tool, a relaxation mode and entertainment through gamified activities. The PTC provides a closed-loop sensorimotor learning, interaction and training system. Neurocognitive diagnostic tools developed in our research group enable the SPC to identify user-specific problems in execution of action sequences based on measured the memory structures. The PTC will then adapt the training routines and provide adequate feedback.
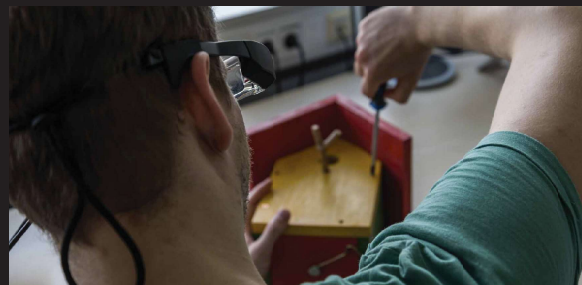
Special software from cognitive science enables the prediction of human action errors for individualized user assistance, e.g. using intelligent smart glasses

Ludwig Vogel and Ellen Schack receiving the award "Landmarks in the Land of Ideas" for the ADAMAAS project, in June 2018

Adaptive and Mobile Action in Daily Living Activities (ADAMAAS)

Intelligent technical systems can use the results of mental representation analyses for adapting to individual expertise. In a recent project at Bielefeld University's Cognitive Interaction Technology - Excellence Center (CITEC), smart glasses were used to assist elderly and disabled people in different activities. The so-called ADAMAAS glasses use augmented reality and eye tracking technology to show helpful illustrations and virtual 3D

animations overlaid with real world objects. This reduces unwanted distraction from the task due to visual clutter. A cognitive diagnostics component uses information about individual mental representation structures to determine in which action steps this assistance is required.

Researchers from the NCA group co-developed and tested the assistance system with mentally challenged people in an educational setting, as well as with elderly citizens from a senior centre. Exemplarily, the system assisted the tasks of assembling wooden birdhouses and interacting with a modern high-tech coffee machine. Qualitative and quantitative user test results showed that the system prototype was considered helpful and already had better usability than average technical systems.

The potential future applications for assistance based on analyses of human memory structures on are theoretically almost unlimited. Currently, NCA researchers work on a follow-up project, which aims at supporting workers in advanced industrial applications. In a few years, intelligent smart glasses could easily be programmed to assist in new activities – just like a universal remote control for hi-fi devices in the living room. NCA Professor Thomas Schack expects that

such next-generation assistance systems will help personal development and live a more satisfying life by enabling them to engage in new activities. The scientists predict that intelligent smart glasses like the ADAMAAS system from Bielefeld may soon be widely used as a cognitive assistance device during our daily life. In June 2018, project ADAMAAS was awarded as one of 100 innovations that are considered Germany's most valuable resources in the competition "Landmarks in the Land of Ideas", under the patronage of the German Federal President F.W. Steinmeier.

The initiative Germany – Land of Ideas is the joint initiative of the German Federal Government and German industry, represented by the Federal Association of German Industry (BDI)

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