NEW PERSPECTIVES ON HUMAN PERFORMANCE

The Neurocognition and Action research group explores human performance and optimises learning processes

Motor activity and motion intelligence have been central dimensions of biological organisms for millions of years. Important stages in evolution are mainly based on the establishment of new functional links between the motor system, related memory structures and perception. In human evolution, refined motor actions like dance or sports have always been important elements of all cultures.

The cognitive architecture of human action

As we have learned from an evolutionary perspective, and from cognitive science during recent years, cognitive and motor process underlying actions are strongly interconnected. From our point of view, human motor actions are not isolated events with defined start and endpoints, but are built upon evolved hierarchical structures consisting of different levels and modules. Cyclic movements like walking, swimming or cycling are controlled by very old neurophysiological structures in our brains. In contrast, goal-directed manual actions required for tool use, like turning a screw, are controlled by different brain structures that are much younger in evolutionary terms. In our understanding, such distinctive goal-directed actions are performed on the basis of precise representations in motor memory.

Fig. 2 In co-operation with the neuroinformatics group and other partners within CITEC, we investigate familiarisation with objects through manual exploration, connecting vision, touch, representation and language

To learn about building blocks of motor performance in our memory and underlying brain structures, the Neurocognition and Action – Biomechanics Research Group (NCA) investigates biological motion in natural and artificial (e.g. virtual reality) environments. The main focus of our research is the neurocognitive architecture of human motor action and its adaptability under various conditions. For this purpose, we use state-of-the-art research methods to investigate the neurocognitive organisation and kinematic parameters of human motor functions.

Fig. 1 The Cognition and Action Laboratories (Coala) represent a cluster of seven different, well-equipped laboratories for conducting experimental studies investigating kinematic, cognitive and perceptual processes in human motor action

Understanding the neurocognitive architecture of actions based on empirical research is, on the one hand, an important step for applied fields, like mental coaching of athletes in high-performance sports or rehabilitation. On the other hand, it is fundamental for the growing field of cognitive robotics, particularly for the central goal to elevate the currently still rigid action repertoire of robots to a level that allows the robot to select and adjust its actions flexibly, according to the varying demands of real-world scenarios.

Building bridges between biological and technical systems

For smooth interactions with humans, a robot or virtual avatar should be able to establish and maintain a shared focus of attention with its human partner or instructor. Furthermore, it should react to commands offered in a 'natural' format, such as speech, gesture and demonstration. To address research questions arising from these requirements, 30 research groups from five faculties have jointly established the Centre of Excellence: 'Cognitive Interaction Technology' (CITEC) at Bielefeld University, which is funded as a part of the German Excellence Initiative.

CITEC offers the appropriate infrastructure for approaching respective research topics from an interdisciplinary perspective. Among the key issues addressed are the questions of how structured representations can arise during skill acquisition, and how the underlying processes can be replicated on robotic platforms. Working towards this common goal, we translate our findings from studies of human movements and related representation into theoretical models that can guide the implementation of corresponding features on cognitive robot architectures.

Action representation as a basis for human-robot interactions

The development of appropriate mental action representation plays a central role in the control of actions and interactions between humans and technical systems by enabling agents to select and combine effective sources of information. Regardless of whether a surgeon has to select the appropriate instrument for an operation; a mechanic – a suitable tool for repairing an engine; or a basketball player – which member of the team to pass the ball to, agents use their mental representations to identify functionally relevant sensory inputs.

The results of our experimental studies support the hypothesis that voluntary movements are planned, executed, and stored in memory as representations of their anticipated perceptual effects. We investigate shared mental action representations to design intelligent technical systems with improved anticipation and interaction capabilities, particularly for rehabilitation, sports and everyday support of the elderly.

Fig. 3 ADAMAAS: The glasses are meant to provide assistance for activities such as baking a cake, making coffee, repairing a bicycle, or even practising yoga

Seeing the world through assistive glasses (ADAMAAS)

As one recent example of our research lines, the ADAMAAS project (Adaptive and Mobile Action Assistance in Daily Living Activities), funded by the German Federal Ministry for Education and Research, focuses on the development of a mobile adaptive assistance system in the form of intelligent glasses that provide unobtrusive and intuitive support in everyday situations.

The system will identify problems in ongoing action processes, react to mistakes and provide context-related assistance in textual, pictorial or avatar-based formats superimposed on a transparent virtual display. The technical platform is provided by the eye-tracking specialist SensoMotoric Instruments (SMI) (www.smivision.com). This project integrates mental representation analysis, eye-tracking, physiological measures (pulse, heart rate), computer vision (object and action recognition) and augmented reality with modern diagnostics and corrective intervention techniques. The major perspective that distinguishes ADAMAAS from stationary diagnostic systems and conventional head-mounted displays is its ability to react to errors in real time, provide individualised feedback for action support, and learn from expert models as well as the individual behaviour of the user.

Conclusion

Human performance is on one side rooted in the profoundness of biological evolution and has on the other side recently matured to a point where it can profit from technical systems. The lines of research presented here can help us to understand the cognitive background of human performance. Furthermore this research forms the basis for building artificial cognitive systems that can interact with a human in a more intuitive way, and also acquire new skills by learning. In this context it is clearly advantageous for a real or a virtual coach to know how mental structures form, stabilise, and change in daily action. A coach or a technical system, like intelligent glasses, which possesses such knowledge is better able to address the individual subject on his or her current level of learning, and shape instructions to optimise learning processes and to maximise performance.

Universität Bielefeld

Professor Dr Thomas Schack
Head of the Neurocognition and Action – Research Group
Head of the Graduate School, 'Cognitive Interaction Technology'
Vice-President of the International Society of Sportpsychology
Bielefeld University, Germany

tel: +49 (521) 106 5127

thomas.schack@uni-bielefeld.de
http://www.neurocognition.de/