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Mirror neuronsand human-robot interaction in assembly cells

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Abstract

When interacting with a robot, the level of mental workload, comfort and trust during the interaction are decisive factors for an effective interaction. Hence, current research focuses on the concept, whether ascribing gantry robot in assembly with anthropomorphic movements can lead to a better anticipation of its behavior by the human operator.Therefore, in an empirical study the effect of different degrees of anthropomorphism should be compared. This is based on the scientific research concerning the neural activity of the human brain when watching someone performing an action. Within the study videos of a virtual gantry robot and a digital human model during placing movements were designed to use in the functional magnetic resonance imaging (fMRI). The aim is to investigate the underlying brain mechanism during observing the movements of the two models.

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1. Introduction

When considering the cooperation between humans and robot in assembly cells, it is necessary to ensure occupational safety. Besides this aspect, when working with a robotic co-worker, the level of stress, strain, comfort and trust during the interaction are also decisive factors for an effective interaction. To take all these variables into consideration, the field of human-robot interaction should focus on the concept of anthropomorphism, i.e. the simulation of human characteristics by non-human agents such as robots. By using anthropomorphism, a higher level of safety and user acceptance can be achieved [1]. In industrial robotics however, transferring anthropomorphism in appearance might be difficult to do. Hence, current investigations focus on the question,

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whether an industrial gantry robot with anthropomorphic movements can lead to a better anticipation of its behavior by the human operator. This idea is mainly based on the results from the neuro-scientific research on the effects of action observation on the behavior and the neural activity of the beholder. The results demonstrate that observation of actions which belong to our motor repertoire activate specialized brain areas in our brains and make our own movements faster. These special brain areas belong to the so-called Mirror Neuron System (MNS) and are activated both by action performance and observation of other humans' actions [2]. There is evidence, that the MNS is crucial for the recognition of the content and the intention of actions. Hence, due to a stronger activation of the MNS anthropomorphic robot movements are more effectively perceived and intentionally followed than conventional robotic movement.

For this reason, the work that will be presented within this paper focuses on the effect of different degrees of anthropomorphism, in particular in motion behavior of a gantry robot in comparison to a digital human model, on human motion perception. To measure the brain activity, videos of a virtual gantry robot and a digital human model were designed to use in the functional magnetic resonance imaging (fMRI). In order to generate the anthropomorphic movement data, a preliminary experiment was conducted using an infrared optical tracking system. Hence, human motion trajectories during placing an object were recorded. The motion data was analyzed to compute the joint angles of the human arm during the placing movement. This information was used to drive the model of the virtual gantry robot and a digital human model. This paper includes a detailed description of the methodology i.e. the producing of the videos with different degrees of anthropomorphism and the the first results of a pilot fMRI scan to validate the stimuli.

2. Mirror neurons and human-robot interaction

Mirror neurons are a class of neurons that become active both when individuals perform a specific action and when they observe a similar action done by others and have been originally discovered in special brain areas of the monkey [3].Afterwards,they were also confirmed in the human brain by several neuroimaging experiments [4]. The main function of the MNS is to understand what another person is doing. Some studies have tried to investigate human mirror neuron activation during observation of robotic actions and had controversial discussions about the activation of the MNS in human brains to robots. Tai et al. [5] in a Positron Emission Tomography (PET) examined movement sequences that were repeated identical but could not prove any significant mirror neuron activation of the humans during monitoring an industrial robot. They presented videos in which either a human or a robot arm grasped an object. They could prove grasping action performed by the human elicited a significant neural response in the MNS, while the observation of the same action by the robot didn't show the same activation. The conclusion was that the human MNS is only activated when watching humans performing grasping actions. In another PET study Perani et al. [6] investigated whether observation of real or virtual hands engages the same activations in the human brain. Their results have shown that only the monitoring of biological agents' actions activates the areas associated to the MNS. Nevertheless, Gazzola et al. [7]investigated the neural activation by the observation of human and robotic actions by using fMRI. They compared videos of simple and complex movements performed either by a human or by an industrial robot with only one degree of freedom and a constant velocity curve. However, the authors found the same activations for human and robotic actions. Gazzola and colleagues explained these contrasting results showing that the presentation of exactly the same robotic action several times does not activate the MNS. In an EEG study by Oberman and colleagues [8] a similar result could be proven. They investigated whether the monitoring of a robot hand performing either a grasping action, or a pantomimed grasp without an object would activate the MNS. The aim was to determine the characteristics of the visual stimuli which evoke MNS activation. Results revealed no difference in the activation of the MNS between two stimuli. AlsoChaminade et al. [9] showed no differences in the activation of thesebrain areas during the watching robotic agents and humans. Accordingly, robotic agents can evoke a similar MNS activation as humans do.

The need of producing anthropomorphic robots able to establish a natural interaction with the human counterpartin different areas like the industryis becoming more and more relevant. Furthermore, in contrast to traditional approaches in industrial robotics, there are an increasing number of new concepts for automation solutions that combine appearance characteristics of an industrial robot and a humanoid such as Yumi from ABB [10] and Baxter or Sawyer from Rethink Robotics [11,12]. This developmentimplies the necessity of designing new