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Introductory Chapter: Transdisciplinary Considerations on Assistive and Rehabilitation Systems

Yves Rybarczyk

1. Introduction

Interacting with an assistive or rehabilitation device involves an adaptation of the cognitive and sensorimotor skills of the human being. This fact suggests that a successful development of such a system should imply transdisciplinary studies that consider both technological and psychological issues. **Figure 1** is a systematic representation that describes the phenomena that occur when an individual has to carry out an action mediated through an artefact [1]. Natural mechanisms enable the users to adapt their behaviours to the new situation. Nevertheless, this natural phenomenon presents certain limits and artificial implementations which could be necessary to reduce the gap between the human operator and the machine. The next two sections explain the processes that underlie the natural adaptation

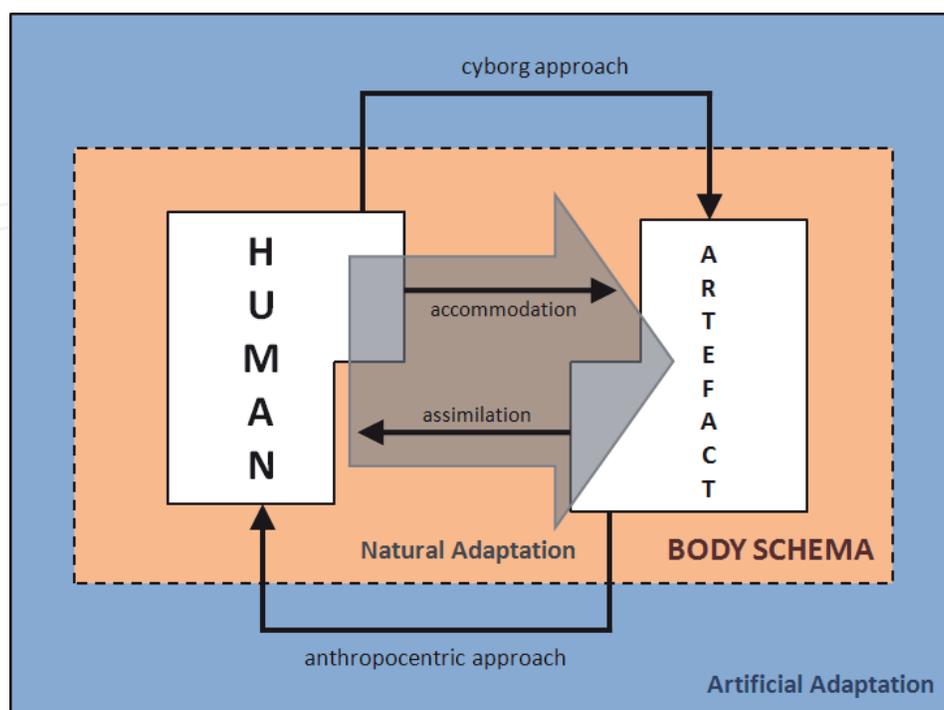


Figure 1.
Natural and artificial processes of adaptation that emerge or can be implemented in a context of human-machine interaction.

happening during the interaction with a tool and how this adaptation can be boosted by technological transformations of the artefact based on an anthropocentric approach.

2. Natural adaptation

According to Piaget [2] the adaptation to a new situation is supported by two complementary mechanisms described as assimilation and accommodation. This finding is based on studies in developmental psychology. Let us take the example of the action of banging, which is one of the favourite activities of the babies to explore the environment. The fact that the young children tend to replicate this same activity on different objects means that the scheme is assimilated by the individual. However, in certain situations it could be improper to reproduce a banging activity, in particular when the object is fragile like an egg. Since, it is not possible to apply the same scheme anymore, a transformation or accommodation of this pre-existing scheme is required. The same process seems to happen in adults when they have to complete an action mediated by an artefact [3]. According to the degree of familiarity with a new object and previous experience with properties of this object, the user will have to use former schemes (assimilation) and/or acquire new ones (accommodation) to properly interact with the artefact.

Once the appropriate schemes are established, a phenomenon of integration of the artefact into the body schema of the user can be observed. Neurophysiological evidences support this claim. Iriki et al. [4] recorded the activity of bimodal neurons of the monkey's brain that code for both visual and somatosensorial information of the animal's arm. The yellow, in **Figure 2** (left panel), is the space that triggers an activation of these neurons if a stimulus is placed in this area. If we let the monkey manipulate a rake for a relative short period of time, we can observe that the dimension of the area increases in such a way that it includes the length of the tool (**Figure 2**, right panel). A similar result was obtained in a more sophisticated setup, in which the animal indirectly perceived its body through a video screen [5]. These outcomes tend to demonstrate that, after manipulation, a device could be processed by the brain as an extension of the biological body. It is to mention that such neurons also exist in the human brain, which suggests that the same integration of an artefact in the body schema should occur in the case of a human operator.

Nevertheless, these proofs of alteration of the body schema are only demonstrated with basic equipment, in which the interaction is relatively straightforward.

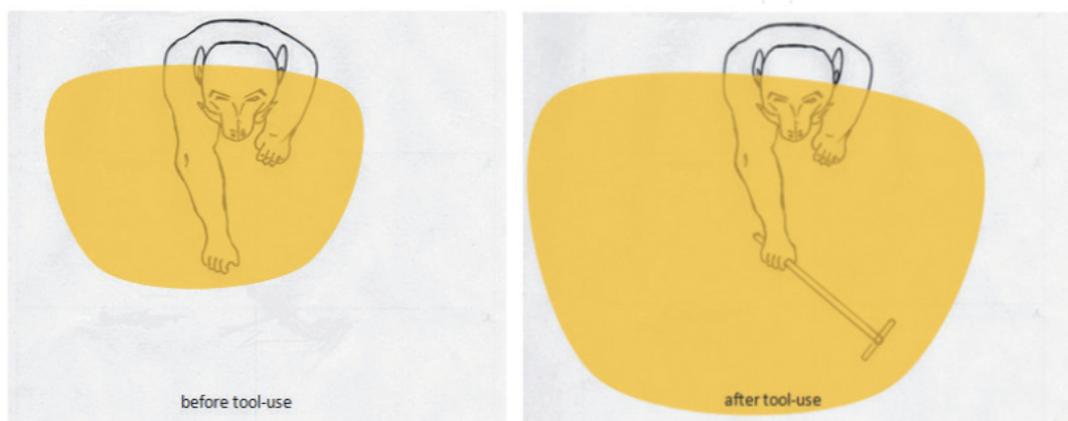


Figure 2. Representation of the area (in yellow) coded by the bimodal neurons, before (left panel) and after (right panel) tool use.

It can be assumed that the natural adaptation would face its limits if the interactive system becomes more complex. In order to overcome these limitations, the next section presents successful case studies that implement an anthropocentric approach to promote an adaptation by assimilation.

3. Artificial adaptation

The application of an anthropocentric approach consists of modelling and implementing human-like behaviours in the assistive system. This method was applied in the context of the ARPH project, which consisted of developing a telerobot to increase the autonomy of motor disabled people [6]. The robot was composed of a robotic arm mounted on a mobile platform. The main limitation faced by the teleoperator was the reduced field of view of the robot's camera, which made difficult the remote control of the vehicle. Researches in experimental psychology show that walkers [7] or drivers [8] who have to change their direction tend to look to the inner part of the trajectory. It seems that the tangent point of the curve provides the individual with the most relevant information to guide the movement. This bio-inspired model of visuomotor anticipation over the locomotion was implemented on the assistive robot and compared to a machine-like behaviour [9]. The results show that the best performances in terms of velocity (completion time) and safety (number of collisions) are obtained with the human-like behaviour. Besides the raw performance, the quality of the robot control is also improved with the visuomotor anticipation, since the vehicle exhibits less jerky trajectories (**Figure 3**). This more natural way of driving suggests a better adaptation to the system when the machine replicates human features than when these characteristics are absent.

Another example of the benefit of the anthropocentric approach was observed with a fundamental law that characterises the human motricity, called 2/3 power law [10]. This law defines the relationship between the velocity and the curvature of the biological movements. It states that the angular velocity of the end effector is proportional to the two-thirds root of its curvature or, equivalently, that the instantaneous tangential velocity (v_t) is proportional to the third root of the radius of curvature (r_t), as described in Eq. (1). In other words, it means that the velocity of the movement decreases in the highly curved parts of the trajectory and increases when the trajectory becomes straighter. Rybarczyk and Carvalho [11] have

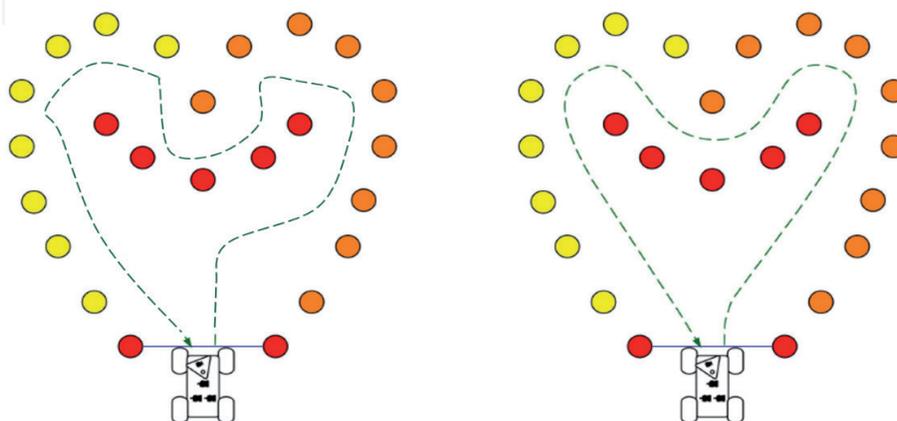


Figure 3. Characteristics of the trajectories performed by a teleoperator when a machine-like (left panel) vs. a human-like (right panel) behaviour is implemented on a remote-controlled robot, to note the smoother path when the bio-inspired model is present.

demonstrated that a teleoperator adapts better to a remote-controlled robot when the 2/3 power law is implemented on the vehicle;

$$v_t = k r_t^{-\frac{1}{3}} \quad (1)$$

4. Conclusions

In line with this introductory chapter, the remaining of the book confirms that several scientific areas are involved in the development of assistive and rehabilitation systems. First of all, in terms of computer sciences, at least five specialties are represented: (i) software engineering, for the proper development of the applications; (ii) artificial intelligence, for the implementation and assessment of smart behaviours; (iii) health computing, to adapt the platform to the medical requirements; (iv) serious games, to increase the motivation of the patients; and (v) affective computing, to interpret the emotional state of the user. The second important area is human factors and ergonomics, which focus on (i) human-centred design, to make sure that the system is user-friendly, and (ii) user experience, to perform usability and accessibility studies. Finally, human sciences (psychology and neurosciences) and health sciences (paramedical fields) have a key role in (i) the design of experimental protocols, (ii) data analyses and (iii) adaptation of the traditional therapy to the new technologies. The next chapters address the interconnection between these complementary areas through the development of solutions for both assistive and rehabilitation purposes.

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