Automation Technologies and Assembly Workers with Cognitive Disabilities

Enabling Collaboration and Delivering the Experience

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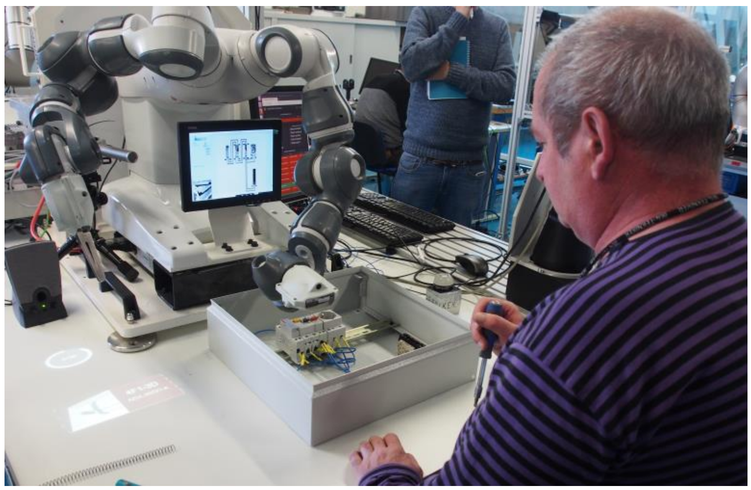

Figure 1: Worker with intellectual disabilities assembling an electrical cabinet in collaboration with a cobot. The robot checks the cables the worker has just connected and informs the worker if an error is found, giving them an opportunity to correct it.

Automation technologies are transforming work, and this affects workers with any profile, including workers with disabilities, for whom technologies create new and exciting employment opportunities. In this position paper, we outline our research work on the introduction of some such technologies in real industrial production environments where assembly workers are persons with cognitive disabilities. We focus on collaborating with a robot that complements the workers in cognitively demanding tasks in an assembly job. We also report the ease with which workers with cognitive disabilities understood and could use virtual reality for training programs. As a main message, we defend that design-for-all principles, as used in our work, result in more usable systems and in better designs from which every worker can benefit, regardless of disabilities.

CCS CONCEPTS • Human-centered computing • Accessibility • Accessibility systems and tools

Additional Keywords and Phrases: collaborative robot, virtual reality, augmented reality, worker with cognitive disabilities, factory of the future, automation, work satisfaction

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1 INTRODUCTION

Automation is transforming work for every person in society, including for workers with disabilities. Taking a social inclusion stance, persons with cognitive disabilities have the same right as any other member of society to access fulfilling jobs [3]. Workers with cognitive disabilities (WCDs) in industry show aspirations to develop skills necessary to occupy specific jobs in their organizations and to reach work satisfaction [8].

With the growing transformation of work through automation, an opportunity opens up to make workplaces accessible as never before, if the right approach to design is taken. What is more, when effort is invested in designing automated workplaces following the principles of *design-for-all* [2], universal usability and accessibility are already built into the system, and benefits will reach users across the scope of possible worker profiles, regardless of disability. To fit a specific industry job, more relevant aspects of a worker profile include skill sets, capacities, capabilities, preferences, to name some. All of these will vary depending on factors such as age, experience, cultural background, and existing disabilities. From this perspective, designing automation in workplaces that also considers constraining requirements from workers with disabilities is a driver to obtain solutions with a broadly usable baseline.

Disabilities can be motor, sensory, mental or cognitive (often a combination of some of these) [4]. In this position paper, we focus on the opportunities opening up for workers with cognitive disabilities, comprising a very broad and heterogeneous group within the population, who face conditions ranging from mild to heavily limiting [10].

Currently, industrial organizations providing sheltered employment [12] for workers with cognitive disabilities re-engineer their assembly lines by fragmentating processes into simplified subtasks that are allocated to workers based on their profiles [9]. This is a costly process that does not deliver the flexibility required by short batch production. As we show below, design-for-all principles, together with innovative allocation of tasks to human and automation, and interface designs for natural and multimodal interaction, can enable workers while also delivering the right experience. The knowhow shared in this position paper was obtained through the development one of the use cases in the MANUWORK project[1].

2 RESEARCH APPROACH AND METHODS

An underlying question was whether WCDs could adapt to some of the new production technologies, understand them, and tolerate them in the workplace, or even benefit from them and be willing to adopt them. For that, a set of technologies were analyzed, tested, and in some cases used in realistic production processes (replicas of real processes).

The technologies included were: Collaborative robots, Augmented reality (projected on the workspace or obtained through head mounted devices), Fully immersive virtual reality, and Exoskeletons.

For each technology and for the extent of the evaluation that was conducted with it, stakeholders were involved. First, an expert evaluation committee was named, which included members with most of the following profiles: Support technician specialized in production processes; Support personnel on training and job induction processes; Management responsible for each production process; Clinical psychologist; Ergonomist; Expert in the adaptation of production processes for persons with disabilities; Expert in prevention of health and

[1] http://www.manuwork.eu/

safety hazards; Interaction design experts; Technologists (experienced providers of the automation technologies).

In addition, assembly workers (WCDs) were recruited for each study. A mix of worker profiles with different levels of experience and capabilities to carry out the intended assembly work were recruited.

Figure 2: Participant in user study (wiring guided by collaborative robot) is responding to questionnaires. *Left*: interpreting questions with the help of an assistant. *Centre*: rating the experience based on emoticons. *Right*: expectations and impressions expressed in drawing

The research effort aimed at recording the experience with the technology at three points in time:

- **Before encountering the technology**. Round table discussions were held between the participants (WCDs) and the expert committee. During these, prior knowledge and experience, or awareness about the existence of the technology were discussed and recorded. Participants were asked to express in drawing (Figure 2, Right) what they expected was going to happen and what the experience would be like (e.g., if a robot, what it would look like, what size, with or without legs, head, talking or not, male or female…). Worker satisfaction of WCDs and support personnel was assessed with an ad hoc questionnaire.
- **During the interaction**. All reactions and interactions were recorded for later analysis (e.g., video capture, note taking by the observing expert). Think aloud from the participants was encouraged by a trusted facilitator that dialogued with them. In some cases, standard post task questionnaires (e.g., SEQ [11]) and post study questionnaires (e.g., SUS [1]) were administered. Ad-hoc questionnaires were also produced, using easy-to-read guidelines [13]. We found that most participants needed assistance to understand and respond to questionnaires, the standard questionnaires in particular.
- **After having used the technology**. Evaluation of the experience was conducted after the first experience and, in some cases, after at least one month of daily exposure to the technology. New round table discussions and drawing expression sessions were conducted. Worker satisfaction of WCDs and support personnel was assessed again.

3 INTRODUCING INDUSTRIAL AUTOMATION TECHNOLOGIES TO WORKERS

This section focuses on two of the technologies experienced by WCDs in our studies: robots and virtual reality.

3.1 Collaborative Robot

One of the more challenging assembly jobs for WCDs is the wiring of electrical cabinets. Although these workers are normally very effective at connecting cables with a screwdriver, they find a barrier in having to connect them according to documents with electrical schematics, which they cannot interpret. For this reason, traditionally only WCDs with the highest cognitive capacity could opt for this job.

In partnering with a robot, the traditional distribution of tasks, where the human should undertake problem solving in all its forms, was not viable. In our intervention [5–7], we delegated on the robot the complexity of interpreting the assembly schematics and deciding a sequence for wiring. Then, the robot guided the human worker, cable by cable, by indicating with a laser beam when exactly the cable held in hand should be connected (see Figure 3). Afterwards, the robot inspected all connections visually (see Figure 1) and it could even pull mechanically with its fingers from each connected cable, to check if every connection were secure.

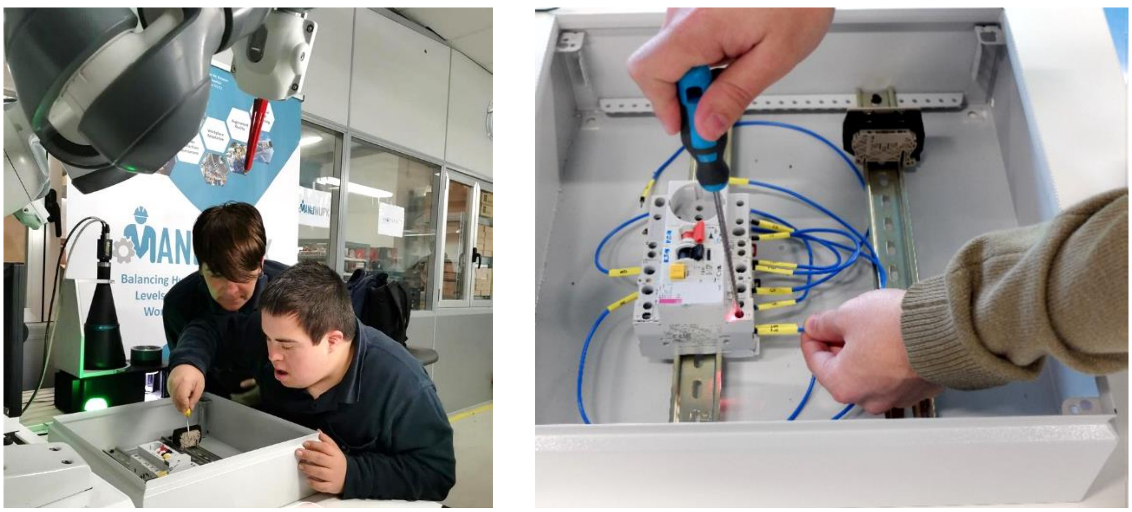

Figure 3: WCD, who cannot read the electrical schematics, is wiring an electrical cabinet under the guidance of the robot that has parsed the schematics. *Left*: a WCD being instructed in the process of wiring guided by the robot. *Right*: a WCD is wiring a cable to the connector on which the robot is highlighting the red laser beam from its hand.

As a result of this intervention, the percentage of all WCDs in the organisation that were eligible for this job grew from 15% to 85%. This was also recorded as a significant boost in confidence, satisfaction and perception of prestige in their organisation, as expressed by many participants.

We learned that it was essential that the robot preserved the level of knowledge and initiative of workers, never attempting to relegate them to a second level by imposing specific ways of doing things. As workers became proficient, the robot had to step back and limit itself to quality check routines.

3.2 Virtual Reality

One of the primary roles of virtual reality (VR) in the factory of the future is the training of human workers in new jobs and procedures. We conducted training sessions with WCDs who had not previously used VR. We found that the behaviour and reactions of workers with a range of disabilities were comparable to the reactions observed in the general population. The more challenging experiences in fully immersive environments were related to teletransportation, although most learned to understand it after dedicated one-to-one instruction. In some cases, the interaction of real objects and people that did not appear in the virtual scenario was reported to be disconcerting. This means that such external objects need to be introduced carefully to begin with. We also observed great resourcefulness from a participant on a motorized wheelchair (Figure 4, left), who did not have difficulties when leaving one of the controllers on her lap (and thus the hand visualization in the virtual world) to have her hand free in the real world and move her wheelchair around.

Figure 4: First experience in a VR training session. *Left*: a worker with lower body motion impairment, utilizing a motorized wheelchair. *Right*: a worker with cognitive disability (Down syndrome)

4 CONCLUSIONS

From the research we have conducted with WCDs and technologies for the factory of the future, we have consistently observed that the reactions and attitudes these users have to the technology and to its uses in work contexts are similar to those observed in the general workforce. A reason for this good acceptance seems to be that WCDs are young on average, and technologically literate (e.g., they are active in social networks with their smart devices). Thus, technology was perceived as friendly and exciting, not threatening as it is sometimes portrayed in popular culture.

We saw that, also with WCDs, preserving control and a sense of agency is very important. Multimodal interfaces should be redundant in the information they present, and the user should be able to attend to the channels of choice without missing anything essential.

Many of the limitations of WCDs are incidentally found in the regular workforce, and systems designed for all have the potential to benefit every user.

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