Preliminary development of the Psychological Factors Assessment Framework for manufacturing human-robot collaboration

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ABSTRACT

Robots, although not new in manufacturing, are still only just being directly integrated with human operators. Although timely and measured human factors integration in technology development can increase its acceptance, the impacts on manufacturing operators are still largely unknown. The proposed work described in this paper discusses the SHERLOCK (seamless and safe human-centred robotic applications for novel collaborative workplace) project approach to human factors integration that aims to develop a standardised tool for evaluating the impacts of robotics in manufacturing (psychological factors assessment framework). Four industrial use case studies of new collaborative applications will allow investigations of changes in operators' psychological states depending on the robot characteristics and assembly requirements. This analysis will enable the development of the framework, which will allow quicker assessment of psychological factors and recommendations for operator needs and requirements in a variety of manufacturing applications.

KEYWORDS

Human-robot collaboration, manufacturing, psychological safety factors

Introduction

Automation and robotics are becoming increasingly ubiquitous and with an introduction of collaborativity the robotics, manufacturing sector foresees significant increase in efficiency and productivity. Despite a substantial amount of research from the engineering perspective (Matsas and Vosniakos, 2017; Zhou et al., 2014), little has been investigated on the social aspects of industrial robots. There is emerging research on the integration of new technology from the organisation's point of view (Moniz and Krings, 2016), yet only limited work has been done on psychological factors in the field of manufacturing (Charalambous et al., 2013; Eimontaite et al., 2016; Tang et al., 2014).

The majority of technology integration and acceptance work does not cover robotics and mainly concerns identifying effective ways of integrating incremental technology (Venkatesh, 2000). Yet industrial robotics is a radical rather than incremental technology, so relying on these technology acceptance models is not enough to provide efficient guidance on successful collaborative robot integration in industry. Work by Charalambous and colleagues (Charalambous et al., 2017; 2015; 2013) has investigated various aspects of robot trust in manufacturing, and provided early foundations for exploring how organisational factors (such as communication, training and development, employee participation, etc.) significantly influence the success of robot integration in a manufacturing context.

Psychological factors play an important role that affects operators' safety, wellbeing and productivity, and these are affected by characteristics of a robot system. The transparency of robot behaviour (for example the operator's ability to predict how and where a robot will move) influences levels of trust and acceptance while working with robots (Kuz et al., 2015; Tang et al., 2014). In addition, a robot's physical characteristics such as its size and speed are related to cognitive load – the greater the robot size and the faster it moves the more mental strain humans experience (Arai et al., 2010).

Taking all things into account, there is a clear need for a cohesive study of factors that affect the successful integration of robots in manufacturing and, in particular, an interdisciplinary and holistic investigation (Moniz and Krings, 2016). Human factors work within the European Commission funded SHERLOCK project (seamless and safe human-centred robotic applications for novel collaborative workplaces) aims to develop a psychological factors assessment framework (PFAF) to assist the integration of robotic applications in manufacturing while taking into account operator needs and requirements. This framework will help to draw recommendations for the development and implementation of the robotic process in accordance with operators' psychological safety and preferences. The framework will be developed through four manufacturing use case studies with different types of robotic applications.

Methods

Participants

Participants will be recruited from project partners' factories (use cases). Participants' gender, age, experience and time working on the particular process being adapted by the robot application will be recorded.

Robotic applications

The four case studies in the SHERLOCK project look to introduce robots that vary in payload, application and type of collaboration with the operator.

- **Dual arm mobile collaborative robot** will be able to hold the part, move along the workstation with the operators, and cooperate with them while lifting and positioning the parts on the production shelves.
- **Exoskeleton** will provide physical support for the operator's upper body (arms) during the assembly tasks.
- **High payload collaborative robot** will help with lifting and rotating parts of different size and weight to increase the operator's maximum physical comfort.
- **Low payload collaborative robot** mounted upside down will cooperate with the operator on the assembly by performing repetitive tasks.

Procedure

Stage 1: The observations and the interviews with the operators about the task performed will provide data that will be analysed using a hierarchical task analysis and task decomposition. Verbal interviews with the operators will investigate what parts of the process are perceived as easy or difficult, and which ones are more likely to lead to errors and be regarded as difficult for a novice operator. This analysis will be used to the determine the psychological factors involved in each case study.

Stage 2: During this stage, psychological factors baseline data (specified in by Stage 1) will be collected on the current processes before the SHERLOCK solution is introduced. All the psychological factors within each case study will be explored by engaging with the operators.

Stage 3: This stage will consist of measuring the same psychological factors as measured in Stage 2 with self-report questionnaires. In addition to the self-report measures, behavioural and physiological measures will be collected on (Stage 3.1) the student population with a generic robotic task, and (Stage 3.2) the operators on the first demonstrator of the SHERLOCK technology solutions. The psychological, behavioural and physiological measures will be analysed to establish relationships between them and, critically, to assess the knowledge provided by the measures.

Stage 4: This is the final version of the PFAF that will be tested during the final introduction of the SHERLOCK solution. This stage is aimed at establishing the operator's psychological safety with the final SHERLOCK technological solution, and providing recommendations on how different robotic applications should be implemented in manufacturing.

Materials

The research will involve the use of a combination of questionnaires distributed for the participants to fill in before and after the interaction with a robot. The questionnaires will investigate a range of aspects starting but not limited to body discomfort (Body Discomfort Scale (Li et al., 2017)), cognitive demands (NASA Task Load Index (TLX; Hart and Staveland, 1988)), and factors emerging from human-robot interaction (Trust in Industrial Human-Robot Collaboration (Charalambous et al., 2015)). In addition to the self-report measures, objective measures such as heart rate and electrodermal properties of the skin, emotional valance from face expressions and gaze duration and direction will be captured. These data will be statistically analysed to inform further development of the PFAF and help to provide recommendations for the technological development and integration from an operator's psychological perspective.

Expected outcomes and impact

One of the SHERLOCK project's aims is to develop and validate a tool to provide guidance and recommendations for the introduction of robotic technology in manufacturing. The main impact of this work would relate to an easier and quicker assessment of psychological factors and better integration of human aspects while developing and integrating robotics in manufacturing. The development of PFAF and further application in the manufacturing industry would lead to increased trust and satisfaction of the operators and quicker payoff for the company after the technology introduction.

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