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Measurement of Worker Satisfaction in Automated Systems - Methodology CEN Workshop Agreement

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European Foreword

CWA 17663:2021 has been developed in accordance with the CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – A rapid prototyping to standardization" and with the relevant provisions of CEN/CENELEC Internal Regulations – Part 2. It was agreed on 2021-01-18 by a Workshop of representatives of interested parties, the constitution of which was supported by CEN following the public call for participation made on 2020-04-30. However, this CEN Workshop Agreement does not necessarily reflect the views of all stakeholders that might have an interest in its subject matter.

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This CWA has been proposed by the A4BLUE European Project (funding from the European Commission's Horizon 2020 – The Framework Programme for Research and Innovation (2014 - 2020) under Grant Agreement GA 723828), whose main objective is the development and evaluation of work systems that are adaptive to deal with evolving requirements of manufacturing processes and human

operators. It is proposed in order to fill a gap in existing standards for ergonomics and human-system interaction which deal with usability and its outcomes but do not specifically address the need for accurate and reliable measurement of worker satisfaction in automated work systems.

Introduction

The rapid development of automated work systems (3.1) that have increasingly responsive and self-adapting functions is transforming manual work. As people work ever more closely and collaboratively with automation, these functions will not only be designed to meet performance output requirements but also to satisfy the different preferences and capabilities of individuals. As the success of any system relies on user acceptance and engagement, worker responses should be a critical design consideration. Thus, system designers need to understand which and how system characteristics should be adjusted to optimise the outcomes of human-system interactions.

A key outcome of any system, product or service is the user's resultant state of 'satisfaction', defined as the *"extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations"* (ISO 9241-11:2018). Satisfaction is a latent psychological state/response that cannot be directly observed, similar to other internal cognitive/affective based outcomes like mental workload, stress, etc. User satisfaction is important to the efficacy of human-system interactions at work because numerous studies have demonstrated relationships between workforce satisfaction and productivity/performance as well as on longer term health and well-being outcomes, and have provided notable examples where new work processes have failed due to limited workforce approval and adoption rather than technical or functional issues. Indeed, user satisfaction is identified as one of the three principal outcome components of usability along with 'efficiency' and 'effectiveness' (ISO 9241-11:2018; ISO 6385:2016), as shown in Figure 1.

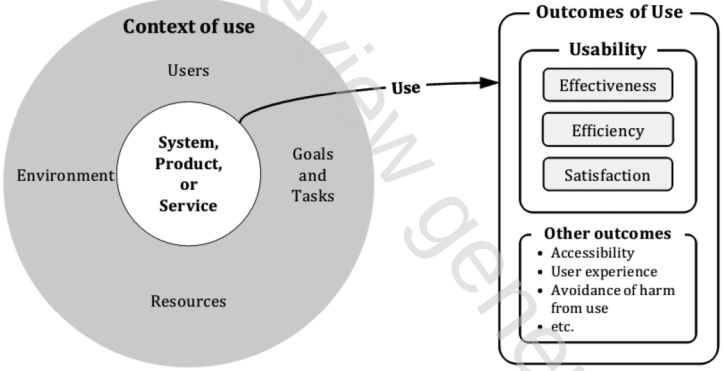

Figure 1 — Satisfaction as one of three 'outcomes of use' usability components (ISO 9241-11:2018)

Current standards advocate that user satisfaction is an important outcome that should be measured as part of ergonomic work system design, similarly to efficiency and effectiveness (ISO 6385:2016, Clause 4.5) but do not provide practical guidance on how to do so. Prescription of specific methods for measuring usability outcomes has been avoided because of the difficulty in addressing variations across contexts: *"[T]here is no single intrinsic measure of the usability of a system, product or service because effectiveness, efficiency and satisfaction depend on the users, goals and other components of the context of use* (3.2) *for which usability is being considered"* (ISO 9241-11:2018, 5.1). As a psychological state/response is an outcome produced by a number of different context-specific characteristics it will comprise a range of different 'dimensions'. For example, the innate characteristic of *extroversion* is just one dimension of personality, and itself comprises a number of sub -dimensions, e.g. assertiveness, sociability, etc. Similarly, a more temporal state or response like comfort is an outcome produced by the characteristics of a context being experienced at the time, so its dimensions will reflect responses to each of those. Thus, to get an overall measurement of a psychological state or responses it is important to

measure all of the key dimensions that contribute to it in relation to the particular context requirements: *"components of satisfaction that are important will depend on the reasons for considering usability"* (ISO 9241-11:2018, 6.4.1). As a single tool would not fulfil the requirements of different systems, tailored/tailorable tools are needed.

'Psychometrics' (psychological measurement) is an approach that offers a robust methodology for developing tailored measures of psychological state or response dimensions, either for general applications or for application across specific contexts. Psychometric tests "attempt to analyse a person in terms of fundamental psychological characteristics" (Smith and Smith, 2005) by applying a "systematic procedure for observing behaviour and describing it with the aid of numerical scales or fixed categories" (Cronbach and Furby, 1970). This systematic procedure of scales or fixed categories will typically consist of multiple items (statements/questions) that have been carefully designed and iteratively tested with statistical procedures to ensure validity and reliability of the results. Multiple items are needed in order to interrogate and measure each of the different dimensions of the particular psychological state or response being investigated.

A number of psychometric tests already exist for measuring satisfaction in different contexts but there are currently no available/published tools for applications in the new context of adaptive automated work systems. Existing tests to measure 'job satisfaction' measure intrinsic factors (task-related factors, e.g. autonomy, creativity, etc) and extrinsic factors (factors external to the task, e.g. pay, conditions, etc). One set of job satisfaction measurement scales is specifically designed for industrial 'blue collar' workers' (Warr, Cook and Wall, 1979). However, no existing tools measure satisfaction in relation to aspects of new adaptive automation work systems. Thus, as user satisfaction may be influenced by a wide range of factors, and those that increase satisfaction are not necessarily the same as those that decrease dissatisfaction, system designers need a tool that will inform them of the particular characteristics of the systems they are designing that will increase or decrease satisfaction.

One particular methodology has been successfully applied to develop a valid and reliable psychometric (3.5) measure in the context of human-system interaction within automated work systems. In previous research conducted by Cranfield University a new measure of trust in industrial robots was created and tested for reliability and validity (Charalambous et al., 2016). As part of the A4BLUE project (Adaptive Automation in Assembly for BLUE collar workers' satisfaction in Evolvable contexts), this particular methodology was utilised towards development of a worker satisfaction measurement tool for the specific context of adaptive automated work systems. It offers a systematic framework for developing psychometric measurement tools to enable bespoke valid and reliable human outcome analysis across systems/contexts. For this reason the current document proposes that it is disseminated as part of a CWA for the measurement of worker satisfaction in automated work systems, which are becoming increasingly adaptive to human interaction.

Although efficiency and effectiveness are cited as key objectives for ergonomic work system design current standards – satisfaction is not (ISO 6385:2016, Clause 3.1). It is also not addressed by any designated standards in the same way as other user outcomes, e.g. mental workload (ISO 10075-1/-2/-3). This reflects that user satisfaction has not before been considered a critical outcome of system design. However, the closer and more collaborative interactions that will be necessary between workers and adaptive automation in future work systems will bring new impacts on safety and performance that are likely to involve satisfaction more critically. The purpose of this CWA is to provide guidance on how the psychometric development methodology applied by Cranfield University and the A4BLUE project can be used to develop bespoke, context-specific, valid and reliable psychometric tools for the measurement of user satisfaction for automated system design.

1 Scope

This CWA sets out guidance for the application of a systematic and reliable methodology which may be used to develop bespoke worker satisfaction (3.7) measurement tools for automated work systems (3.1) design. In doing so, it aims to promote the availability and consistency of robust psychometric (3.5) measurement tools for the design of future manufacturing systems in order to enhance worker satisfaction and, in turn, wider workforce wellbeing and performance outcomes. It does not advocate a single satisfaction measurement tool, because no single measure is universally applicable across different contexts.

The methodology described in this CWA document focuses on worker satisfaction measurement but, as it is based on social science principles for psychometric tool development, is transferable to the development of psychometric measures for measurement of other latent psychological variables (3.4) and other contexts.

The document offers a methodology for assessing psychosocial impacts of automation/human-robot cell design which is independent from risk assessment but could be used to support it. The methodology is not mandatory for a PSR-related workplace design or companies OSH-prevention policies.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
automated work system
a system comprising one or more workers and equipment that includes automated components that act together to perform a work task or goal

3.2
context of use
combination of users, goals and tasks, resources, and environment

3.3
item
an item is a statement or question that is posed to a test participant as part of a survey or questionnaire so that their response indicates their current subjective viewpoint, typically along a numerical scale

3.4
latent variable
unobservable or hidden variables, such as those manifest in human emotion and cognition