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Designing medical interactive systems via assessment of human mental workload

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***Abstract*—In clinical settings, Human-computer systems need to be designed in a way that medical errors are reduced and patient care is enhanced. Inspection methods are usually employed in HCI to assess usability of interactive systems. However, they do not consider the state of the operator while executing a task, the surrounding environment and the task demands. It is argued that assessing performance of operators is fundamental for designing optimal systems with which healthcare can be effectively delivered. The aim of our solution is to assess performance of operators employing the notion of Mental Workload (MWL) this being a construct believed to strongly correlate with performance. The proposal is to develop a model for MWL assessment using supervised machine learning. This model will be evaluated via user studies involving clinicians and operators interacting with a set of medical systems. Assessments of MWL will be compared and validated with objective indexes of performance such as error rate and task execution time.**

***Keywords*-Human Mental Workload; Interactive Systems; Medical applications; Human-Computer Interaction; Machine Learning;**

I. Introduction

In Human-Computer Interaction, inspection methods are usually applied to assess the perceived usability of interactive systems so design alternatives can be evaluated. However, these methods mainly focus on the user interface without considering external factors such as the environment, the context of use and the cognitive state of its users [5], all influencing the human-computer interaction. In medical settings, clinicians, doctors, nurses and in general other operators are often forced to work under pressure with patients whose dependency score can be relative high. Therefore the cognitive state of these operators is constant flux, often affected by period of pressure and stress punctuated by intervals of more calm and relax. As a consequence, merely assessing the usability of medical systems and technologies is likely to be reductive and assessing the performance of operators interacting with them becomes critical. In the literature of Ergonomics and Psychology, several methods have been designed for assessing performance [6]. Several of these consider human Mental Workload (MWL) as the means for predicting performance. MWL is a powerful design concept in Human-Computer Interaction (HCI) [4] and it is extremely important for investigating the interaction of people with computers and other medical devices [1].

It has been extensively documented that mental underload or overload can both negatively affect performance [7], as per figure 1. On one hand, at a low level of MWL, people may often experience annoyance and frustration when processing information, thus increasing reaction time. On the other hand, a high level can also be both problematic and even dangerous, as it leads to confusion, it decreases performance in information processing, and it increases the chances of errors and mistakes. Hence, designers and medical practitioners who are ultimately interested in system or human performance need answers about operator's mental workload at all stages of system design and operation so that design alternatives can be evaluated [2]. In the context of clinical and medical settings, the assumption is that *systems and interfaces tailored to impose optimal mental workload are expected to reduce error-rate and improve patient care.*

MWL can be intuitively defined as the amount of mental work necessary for a person to complete a task over a given period of time. However, in medical and clinical environments we support the view that MWL 'is not an elementary property, rather it emerges from the interaction between the requirements of a task, the circumstances under which it is performed and the skills, behaviours and perceptions of the operator' [3]. This definition supports our view in which merely assessing the usability of an interactive system is not sufficient for designing optimal technologies for medical fields. Rather, consideration of the state and skills of users, the surrounding environment as well as the difficulty of underlying tasks are all important for influencing user's performance with clear consequences on user satisfaction, medical errors and patient care.

II. The research issue

Although a wide range of ad hoc definitions are present in the literature, as well as several applications in the aviation and automobile industry, the concept of MWL has not been sufficiently investigated and applied in medical contexts. The research problem concerns firstly the identification of those factors believed to influence mental workload in clinical operational environments. Secondly it focuses on the development of a model for aggregating these factors towards a meaningful index of mental workload that can

Underload	Optimal Workload	Overload
low sustained attention high reaction time low performance	high user satisfaction high system success low error rate high productivity/safety	high response time/error rate small mental residual capacity low performance

Figure 1. Disadvantages associated to low/high mental workload and advantages of optimal workload

be employed in practice for predicting performance of operators. Formally, the research question that we aim to answer is:

To what extent can a model for predicting performance be developed using the concept of human Mental Workload and techniques from Machine Learning in the context of medicine and health-care?

III. Objectives and methodologies

In order to answer the aforementioned research question, the following objectives are defined:

1) identify definitions of mental workload and applications in medicine and clinical settings
2) identify those factors believed to influence mental workload
3) design a model using machine learning that incorporate identified factors
4) empirically evaluate designed model in clinical settings with real-world technologies

The research methodologies planned for the achievement of aforementioned objectives are:

1) a literature review on mental workload and its definitions in psychology and ergonomics as well as applications in clinical settings.
2) a literature review of those factors believed to influence/shape/inform mental workload in medical and clinical settings .
3) the identification and application of a set of supervised machine learning classifiers that incorporate identified mental workload factors for fitting performance indicators. Gathering of factors will be obtained through user studies involving clinical operators interacting with a set of digital interfaces and medical technologies. Factors will be subjectively gathered via a questionnaire.
4) the evaluation of the selected machine learning classifiers will be performed by comparing their accuracy, precision and recall properties.

IV. Contribution to the body of knowledge

This research will contribute to the body of knowledge firstly by providing a literature review on definitions of mental workload as well as its applications in the field of medicine and health-care. The major contribution will be the development of a machine learning classifier that incorporates factors believed to shape mental workload and able to predict objective indicators of performance. This model is aimed at being a suitable alternative or support to classical inspection methods for assessing usability of medical interactive systems by employing the notions of mental workload. The goal is to provide designers with a robust tool for creating medical devices and technologies mental workload-aware aimed at maximising patient care, reducing medical errors, improving user satisfaction and increasing productivity as well as safety.

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