Gaze Guiding as Support for the Control of Technical Systems

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ABSTRACT

The control of technical systems is often defined by standard operating procedures, e.g. provided by paper-based manuals or decision trees. These procedures specify how a human operator should handle a specific situation occurring in the system control, which might also be safety-critical. This work presents a concept of guiding users’ gaze in such control scenarios of technical systems, which aims at preventing the user from having to leave the control context in order to consult such a paper-based standard operating procedure. Instead, the presented approach fades in information into the control interface based on the current situation of the system and the intended procedure. The work further argues for the use of this technique in the context of refresher-based training to enhance retrieval of once-learned knowledge. This concept, called gaze guiding, has been implemented in a framework in which it can be applied to existing control interfaces. The feasibility of gaze guiding in such control scenarios is demonstrated in a user study with 21 participants.

Keywords: Gaze Guiding, Refresher-Based Training, System Control, Technical Systems

1. INTRODUCTION

According to the New Theory of Disuse introduced by Bjork and Bjork (1992; Bjork 2011), the retrieval strength of once-learned knowledge or abilities is reduced after a period of non-use, while the information is stored permanently in the cognitive memory (storage strength). This leads to a reduction in retrieval, which is generally known as “forgetting”. This is especially true in the context of monitoring and control of (semi-)automated technical systems, in which the human operator is no longer closely embedded in the control loop. As a consequence, the probability of a reduction in retrieval (Kluge et al., 2009) increases, and might lead to error-prone control operations, which can be especially problematic in safety-critical situations of the system. In the worst-case scenario, this can culminate in accidents, with an impact on the environment (Onnasch et al., 2014; Parasuraman et al., 2000; Hamesk et al., 2009).

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To reduce the probability of errors occurring in the monitoring and control of technical systems, refresher training is conducted with the human operators of a system. Refresher training has been shown to be suitable for maintaining the performance level and improving retrieval after a specific time of non-use of the once-learned skill (Kluge et al., 2014). One option for conducting refresher training lies in a simulation of the technical system, such as a process control situation (Kluge & Frank, 2014). This type of process control situation comprises various tasks that have to be performed by the operator. For each task, the operator has to know the standard operating procedures (SOP; Kluge, 2014; Wickens & Hollands, 2000) that are relevant for the handling of normal control or safety-critical situations (Kluge et al., 2009). SOPs describe how the operator has to act in a specific situation and how a situation is specified. For each situation, there are predefined SOPs that have to be known and followed by the operator. Such SOPs can be embodied by decision trees or fixed sequences that have to be followed, e.g. by using a manual (Kluge, 2014). Most SOPs are known well by the operator, but rarely used SOPs may be forgotten (Bjork & Bjork, 2006).

Simulation-driven refresher training can be based on the practical operation of the simulation in specific situations, and offering SOPs as an additional manual which contains the relevant operation sequences for the given situation. Thus, operators have to analyze the situation and then apply the correct operation with the help of the SOP according to their observation. If the operator is unable to apply the correct operation, he/she has to leave the context of the simulation and refresh the missing information by reading the text documentation or by asking the training supervisor. However, this change in context during the refresher training interrupts the learning process and may lead to an increased mental workload (Young et al., 2015). To avoid unnecessary mental workload, we developed a framework that implements a visual mechanism for cueing the operator’s attention to parts of the control interface that are relevant in the context of the simulation situation in order to support the recall of an important SOP.

We call this mechanism of cueing the operator’s attention gaze guiding. This is distinguishable from the term “Gaze Guided”, which implies an interaction process or a system that is controlled by the user’s gaze (Sibert & Jacob, 2000). Gaze guiding is based on the person’s pre-attentive visual perception, which refers to a part of human visual perception that affects the person’s attention before the visual stimulus is intentionally processed by human cognition (Ware, 2004). Examples of pre-attentively perceived visual cues include changes in the shape or color of an object and changes in its direction or speed of movement.

The main contribution of this work is the presentation of the concept and the implementation of a framework for gaze guiding, which was evaluated in a user study with 21 participants conducted in winter 2014. Four different gaze-guiding versions were evaluated by the participants in terms of their design, content and support for retrieval. The study reveals a high feasibility of the concept for guiding the attention of human operators in the control of technical systems, and thereby demonstrates that it is suitable to be used instead of classic refresher training. The effectiveness of the approach in the context of refresher training compared to other approaches is currently being investigated in a more broadly applied experiment. Both studies are based on a simulation of a wastewater treatment facility called WaTrSim (Kluge et al., 2014).

This paper is structured as follows: Section 2 presents related work, addressing in particular previous approaches for cueing users’ attention. This is followed by an introduction to the gaze-guiding framework, which encompasses the description of a formal specification of system states corresponding to the concept of SOPs, the description concept for the gaze-guiding models, and the implementation of the framework (Section 3). Section 4 introduces the conducted user study, including the presentation of the WaTrSim system as well as the results of the study. The final Section 5 provides a conclusion and an outlook on future work.

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