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Explicit or implicit situation awareness? Measuring the situation awareness of train traffic controllers

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ABSTRACT

Previous research on situation awareness (SA) predominantly focused on its explicit, reasoned, conscious features rather than on the implicit, intuitive, unconscious aspects that are often identified with expert operators. This research investigated implicit levels of SA of train traffic controllers (TTCs) in order to contribute to the body of knowledge on rail human factors research and SA. A novel approach was used to uncover levels of implicit SA through a set of three analyses: (1) fairly low SAGAT values with correlations between SAGAT scores and multiple performance indicators; (2) negative correlations between work experience and SAGAT scores; and (3) structurally lower level-1 SA (perception) scores in comparison to level-2 SA (comprehension) scores in accordance with Endsley's three-level model. Two studies were conducted: A pilot study – which focused on SA measurements with TTCs in a monitoring mode ($N = 9$) – and the main study, which involved TTCs from another control center ($N = 20$) and three different disrupted conditions. In the pilot study, SA was measured through the situation-awareness global assessment technique (SAGAT), perceived SA and observed SA, and performance was measured through punctuality and unplanned stops of trains before red signals. In the main study, SA was measured through SAGAT, and perceived SA and multiple performance indicators, such as arrival and departure punctuality and platform consistency, were assessed. In both studies, the set of three analyses showed consistent and persistent indications of the presence of implicit SA. Endsley's three-level model and related SAGAT method can be constrained by the presence of these intuitive, unconscious processes and inconsistent findings on correlations between SAGAT scores and performance. These findings provide insights into the SA of TTCs in the Netherlands and can support the development of training programs and/or the design of a new traffic management system.

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1. Introduction

The cognitive concept of situation awareness (SA) has been widely investigated by the human factors community in the past two decades and across different domains (Endsley, 2015; Sneddon, Mearns, & Flin, 2006). SA can be ascribed to practitioners in complex, dynamic systems that have perceptual and cognitive demanding tasks that are pressured by safe, effective and timely decisions (Endsley, 1995a). The notion of SA is in line with the limits of bounded rationality and bounded awareness, in which individuals are cognitively restrained by, for example, their dependency on sensory (perceptual) input, "computational powers," and situational circumstances (Chugh & Bazerman, 2007; Lipshitz, Klein, Orasanu, & Salas, 2001; Simon, 1983). Despite numerous discussions on situation awareness definitions (e.g. process versus product) and frameworks (e.g. SA residing in the mind versus the system), Endsley's three-level model of SA has received broad support in the human factors community (e.g. Dekker, Hummerdal, & Smith, 2010; Parasuraman, Sheridan, & Wickens, 2008; Sarter & Woods, 1991; Stanton et al., 2006). It is defined as (1) the perception of elements in the environment, (2) the comprehension of these elements, and (3) the projection of these elements in the near future (Endsley, 1988a). The development of SA is a process, which is reflected throughout the three levels and which can also be referred to as situation assessment (Endsley, 1995a). Situation awareness itself is the product from this process. Individual factors such as goals, objectives and expectations influence the situation assessment. Additionally, also task or system factors, such as interface design, stress and workload and automation impact the process of situation awareness. The model draws from traditional information-processing theories, in which a well-developed understanding of the system's dynamics (also known as mental model) is necessary to develop a good situation awareness (Endsley, 2001). Another characteristic of the model is that situation awareness is formulated as an indicator of decision-making, which in turn can predict the level of performance of actions.

The operationalization of the three-level model has so far mainly focused on explicating knowledge (e.g., Salmon, Stanton, Walker, & Green, 2006). For instance, the situation-awareness global assessment technique (SAGAT), which focuses on extracting operators' explicit knowledge through probes during simulator freezes, shows a correlation with performance and has received general acceptance in the human factors community (Salmon et al., 2009). Through SAGAT, a 'snapshot' of the operator's mental model of the situation is captured, a direct measurement of the pilot's knowledge of the situation is obtained and objectively collected (Endsley, 1988b), However, this focus on solely explicating knowledge can be seen as conflicting in accordance to the naturalistic decision-making field. In this research area, an emphasis has been put on investigating operators in their daily work environment, in which this line of research indicates that operators might use their intuition to conduct pattern matching in certain situations (Klein, 2008). Operators may use unconscious processes in order to take rapid decisions. As such, focusing on measuring explicit levels of situation awareness may not be a good reflection of operator's actual cognitive processes.

1.1. Explicit versus implicit situation awareness

A previous literature review on explicit and implicit situation awareness has been conducted by the current authors (Lo, Sehic, & Meijer, 2014). In this review SA has been found, in line with Adams, Tenney, and Pew (1995), as a dynamic mental model of the situation, in which explicit and implicit levels of knowledge can be distinguished. The active knowledge that resides in the working memory can be related to explicit knowledge, while the less active knowledge which cannot be inferred from queries or knowledge probes can be related to implicit knowledge (Croft, Banbury, Butler, & Berry, 2004; Endsley, 1997; Gugerty, 1997). Furthermore, implicit knowledge is considered as unintentional, unconscious, and intuitive. In accordance to Croft et al. (2004) and Durso and Sethumadhavan (2008), implicit SA can also be viewed as implicit processes in SA. In situations of competing attentional demands, these implicit processes are characterized as extremely durable and more robust, and related to an increase in expertise. The relation between expertise and implicit processes is also considered an aspect of the skill, rule, knowledge framework of Rasmussen (1983), which relates little conscious attention or control to the skill-based level, on the contrary to the knowledge-based level.

Previous examples of the operationalization of implicit SA have been through comparisons of recalling probes (such as the SAGAT method) with performance-based or speed/accuracy measurements, such as hostile or friendly aircraft recognition (Croft et al., 2004; Endsley, 2000a; Gugerty, 1997).

In a more general psychological context, these unconscious, automatic cognitive processes are also referred to as "system 1 versus system 2," which operate on a conscious level but more slowly (Kahneman, 2012). Although the role of unconscious processes in terms of both neuropsychological and cognitive mechanisms is recognized within fundamental streams in psychology, researchers are yet to develop a deeper understanding and controversial findings are impeding their progress (e.g., Dijksterhuis, Bos, Nordgren, & van Baaren, 2006; Newell & Shanks, 2014; Reber, 1989).

1.2. Train traffic control

Following the widespread breakup of the railway sector across Europe in the 1990s into multiple commercialized and governmental organizations, there has been a steady increase in research on rail human factors (Knieps, 2013; Van de Velde, 2001; Wilson & Norris, 2005). The de-bundling of the railway sector led to a rather rapidly changing domain in terms of technical requirements, namely the implementation of higher levels of automation, such as automatic route setting and