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Developing information systems to support situational awareness and interaction in time-pressuring crisis situations

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ABSTRACT

Crises (such as a plane accident) require fast and effective responses. In order to respond effectively, actors need to be aware of the situation. Actors who are experts in different fields also need to interact and cooperate with one another. The focus of this study is on theoretical study and model development in which cases are used as material. As a result of the research, we have identified common features in four emergency response cases. We present a model that explains how the actors comprehend the situation and how they interact during the operations. We offer ideas for developing the information systems – often called situation pictures or common operational pictures – that are used in the emergency situations as a means of supporting situational awareness, interaction and decision-making. The results highlight especially the importance of a narrative in situational awareness creation and sharing processes. The results enable actors to develop the processes and the tools to better support emergency response operations.

1. Introduction

During the past few years, we have read news about disasters and other crisis situations that have occurred in different places in the world. One of the most terrible disasters was the earthquake and tsunami in Japan on March 11, 2011, which resulted in more than 15,000 deaths and thousands of injured and missing people. Another terrible disaster occurred on September 7, 2011 when the hockey team Lokomotiv Yaroslavl was travelling to Minsk for the first game of the KHL season when their plane crashed shortly after take-off, causing the death of all the players. In a shocking incident in Norway on July 22, 2011, a gunman opened fire at a summer camp killing 69 and injuring more than 100 people. The bombing attack during the Boston Marathon on April 15, 2013 was also fatal, killing three people and injuring more than 200.

Crises of this kind require a quick and effective response so that the number of deaths and injuries can be minimized. The response demands a high and wide range of expertise. Experts from several fields and teams with high-level situational awareness (SA) need to respond to the situations. SA has to do with how an individual or a team comprehends the situation in which they are operating. SA enables an individual or a team to make the right decisions and communicate with the other individuals and teams who make up the responding social system. SA is usually supported by information systems that improve information production and sharing and support decision-making and actions. To carry out the operations in an efficient way, experts need to have real-time, spatio-temporal situational information (Goodchild, 2010; Seppänen et al., 2013; Steenbruggen et al., 2011). SA and the decision-making are usually supported by information systems called operational pictures (OPs) or situation pictures (Seppänen and Virrantaus, 2010). In joint operations, several actors may share critical information via a common operational picture (COP). COP is an OP shared by more than one actor/party in a particular operation. COP enables all the actors/parties to achieve and share situational information in a geographically distributed environment (Fanti and Beach, 2002; Shelton, 2001; Steenbruggen et al., 2011; Vesterinen, 2008). In a military context, for example, COP is defined as an integrated display that combines maritime, air and ground operations management (Fanti and Beach, 2002).

However, the concepts of OP and COP are not always sufficient solutions to support SA and communication. The two major weaknesses of these concepts are that: (1) They typically support only the management teams, and (2) the concept of COP does not take into account the fact that SA should support the different task and goals of different individuals or teams. The same information is not relevant for every actor. If COP constitutes the collection of all information, it may also disturb the way in which the relevant information is assessed (Endsley et al., 2003). To better support the SA of the several individuals and teams, the information system should take into account the specific information needs of several

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actors and offer a tool for them to communicate with each other. The information system should be tailored to the specific context and scalable so that it supports SA and interaction at all levels of the hierarchical organization.

This research study includes theoretical studies and case studies of emergency response exercises. Our goal was (1) to identify the common features of the cases, (2) to present a model that shows how the SA is created and shared within the organization being studied, and (3) to offer new ideas for information system development. In order to achieve these goals, we have done theoretical research on the theoretical and conceptual framework needed to comprehend and analyze the case studies. This research is limited so that we can stay at a conceptual level. We do not suggest technical implementations for the information system.

This research offers several benefits. It offers ideas that can be used for information system development. It also offers a conceptual framework that is important for understanding the nature of SA at several organization levels in time-pressure situations.

The paper has the following structure. The theoretical framework will be presented in chapter 2. The case studies will be presented in chapter 3. The methods we used to collect data from the cases studies will be presented in chapter 4. The results will be presented in chapter 5. The nature of the research and ideas for the future will be discussed in chapter 6.

2. Theoretical framework

In this study, we have carried out a theoretical study and collected concepts and theories from different fields of science. This has enabled us to understand how SA, interaction, and decision-making should be supported in organizations responding to time-pressure situations. We have studied the different types of knowledge and how this knowledge is used in decision-making, and we have also studied the nature of SA and teams and how individuals and teams make sense of experiences through narratives and with geographic information systems (GIS). The concepts are defined in the following chapters.

2.1. Data, information, and knowledge

Knowledge has to do with subjective human knowing (Nonaka, 1994; Nonaka et al., 2000; Nonaka and von Krogh, 2009; Tsoukas, 1996). In contrast of knowledge, information has to do with external messages that are observed and interpreted against the existing store of knowledge (Nonaka, 1994). The interactive model (data & knowledge → information) specifies that information cannot entirely be separated from the human agent as information processor. Instead, data manifests itself as information when a human agent is interpreting it against his/her existing store of knowledge (Boisot and Canals, 2004; Kettinger and Li, 2010).

2.2. Tacit and explicit knowledge

Knowledge is usually divided into two types: Explicit and tacit knowledge (Dyer and Nobeoka, 2000; Evans, 2008; Grant, 1996; Klein, 2009; Nonaka et al., 2000; Nonaka and von Krogh, 2009; Tsoukas, 1996; Weick and Roberts, 1993). Explicit knowledge has a universal and context-free character. It is accessible through consciousness (Evans, 2008; Nonaka and von Krogh, 2009) and it is easy to express in formal language (Evans, 2008; Grant, 1996; Nonaka et al., 2000; Nonaka and von Krogh, 2009). Some authors also equate explicit knowledge with information and use the terms interchangeably (Dyer and Nobeoka, 2000; Grant, 1996). In contrast to explicit knowledge, tacit knowledge, for example intuitions and practical know-how, is nonverbal and difficult to formalize. It is revealed through its application in a particular context (Dyer and Nobeoka, 2000; Evans, 2008; Grant, 1996; Nonaka et al., 2000; Nonaka and von Krogh, 2009). Tacit knowledge is more difficult to access through conscious choices (Evans, 2008; Nonaka and von Krogh, 2009). Tacit and explicit knowledge are not separate but mutually complementary (Evans, 2008; Nonaka and von Krogh, 2009; Tsoukas, 1996). Tacit knowledge is the necessary component of all knowledge and explicit knowledge is always grounded in a tacit component (Evans, 2008; Klein, 2009; Tsoukas, 1996).

2.3. Two minds

The human mind and mental processes are usually divided into two types. These two minds are called system 1, also called the intuitive, reflexive, old, and unconscious mind, and system 2, also called the intentional, reflective, new, and conscious mind (Evans, 2003, 2008, 2010; Kahneman, 2011; Klein, 2009; Stanovich, 2004). The features of the systems are presented in Table 1.

System 1 includes unconscious mental processes; this covers most of our mental processes. It is fast and automatic by its very nature and effortlessly aids the working memory. System 1 works based on experiences and heuristics, and it is, therefore, biased by its very nature (Kahneman, 2011; Stanovich, 2004). System 1 includes parallel processes and it is capable of handling huge amounts of information at once. However, our conscious minds only receive the final information output given by the processes, while the actual information processing takes place in the unconscious mind (Evans, 2003, 2010; Kahneman, 2011). In system 1, the knowledge is called tacit knowledge (Evans, 2010; Klein, 2009). Human brains typically try to develop so that they can make most of their decisions through system 1 processes, making the decisions as automatically as possible, because system 1 is fast and energy efficient (Baumeister and Tierney, 2012).

System 2 includes conscious mental processes. It is slow, intentional, and employs language. The processes require effort for the working memory. System 2 processes are sequential and available for our conscious attention. System 2 enables us to engage in abstract and hypothetical reasoning (Evans, 2003, 2010; Kahneman, 2011), for example to compare intentionally contrasting options for how to act in a particular situation (Klein, 2009). In system 2, the knowledge is called explicit knowledge (Evans, 2010; Klein, 2009). The human brain typically tries to minimize system 2 processes because they are slow and consume lots of energy (Baumeister and Tierney, 2012).

Human brains seek to adapt to the external world, and to affect it, so that life would be effortless and our brains would stay as energy efficient as possible. Human brains seek to achieve a state of auto pilot. In this kind of setup, system 1 makes almost every decision in our lives. The role of system 2 is to monitor system 1 and intervene when system 1 is going to make bad decisions that are based on biases not suitable for the existing situation (Baumeister and Tierney, 2012; Evans, 2003, 2010; Kahneman, 2011).

Table 1
The features of the two minds.

System 1	System 2
Unconscious mind	Conscious mind
Reflexive	Reflective
Intuitive	Intentional
Low effort	High effort
Fast	Slow
Evolutionarily old	Evolutionarily new
Nonverbal	Linked to language
Parallel	Sequential
Tacit knowledge	Explicit knowledge
Contextualized	Abstract