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RESEARCH ARTICLE

Modelling of situation awareness with perception, attention, and prior and retrospective awareness ☆

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Abstract
Human awareness under different circumstances is complex and non-trivial to understand. Nevertheless, due to the importance of awareness for safety and efficiency in many domains (e.g., the aviation domain), it is necessary to study the processes behind situation awareness, to eliminate possible errors in action selection that may lead to disasters. Interesting models for situation awareness have been presented, mainly from an ecological psychology perspective, but they are debatable with respect to the latest neurocognitive evidences. With the developments in brain imaging and recording techniques, more and more detailed information on complex cognitive processes becomes available. This provides room to further investigate the mechanisms behind many cognitive phenomena, including situation awareness. This paper presents a computational cognitive agent model for situation awareness from the perspective of action selection, which is inspired by neurocognitive evidences. The model integrates bottom-up and top-down cognitive processes, related to various cognitive states: perception, desires, attention, intention, (prior and retrospective) awareness, ownership, feeling, and communication. Based on the model, various cognitive effects can be explained, such as perceptual load, predictive processes, inferential processes, cognitive controlling, unconscious bias, and conscious bias. A model like this will be useful in domains that benefit from complex simulations of socio-technical systems (e.g. the aviation domain) based on computational models of human behaviour. In such domains, existing agent-based simulations are limited, since most of the agent models do not include realistic nature-inspired processes. The validity of

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the model is illustrated based on simulations for the aviation domain, focusing on a particular situation where an agent has biased perception, poor comprehension, habitual driven projection, and conflict between prior and retrospective effects on action execution.

Introduction

The relation between human awareness and action selection is a complex issue, which is the subject of much debate and provides many challenges for further research. Nevertheless; due to the developments in brain imaging and recording techniques, the insight in human brain processes is growing rapidly, which contributes to an improved quality of relevant data and to the development of new methods to explore this most complex system within human anatomy through different dimensions. Human cognitive processes are often grouped into conscious (i.e. accompanied with awareness) and unconscious processes. The understanding of the interplay between conscious and unconscious processes associated with action selection and related phenomena has much improved, especially thanks to the experimental framework proposed by Libet, Gleason, Wright, and Pearl (1983) and later improvements made to it. In the literature, bottom-up cognitive processes have been mapped to unconscious action formation, whereas top-down processes have been related to the conscious action formation (cf. Moore & Haggard, 2008; Engel, Fries, & Singer, 2001; Haggard, 2008; Kiefer, 2007); it seems our action selection process initiates from unconscious phenomena, and that later we develop the conscious experience of this action selection. The unconscious neural activations in the brain seem to be a result of habitual tasks, through the effects of prior learning, which can be automatically activated when a relevant stimulus is perceived (Monsell, 2003). Nevertheless, conscious awareness of action selection also plays an important role and the influence of predictive and inferential processes of action execution has been highlighted by Haggard and co-workers, providing a working mechanism for this process (cf. Moore & Haggard, 2008).

Situation Awareness (SA) can be considered as a subjective quality or interpretation of the awareness of a situation a person is engaged in. When a person is engaged in a situation based on the information that he/she perceives, the attention that is allocated to that information based on his/her subjective desires will develop his/her subjective awareness of the situation. This is the reason why different individuals may have different interpretations of the same situation. The correctness of SA is always relative and its quality can be analysed when a task is performed with an expert critiquing as a benchmark. Due to this complexity and subjective nature of SA, the concept has received many definitions in the literature and according to (Dominguez, 1994) there are more than fifteen definitions about SA; among those, the definition proposed by Endsley (1988) became the most widely used. According to Endsley, SA is:

> ''*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*'' (Endsley, 1995, p. 36).

Based on this definition, Endsley highlighted three elements as the necessary conditions for SA; these are three levels of which one is followed by the other, in order to develop complete (subjective) awareness. These three elements are the following:

(1) Level 1: perception
(2) Level 2: comprehension and
(3) Level 3: projection

Furthermore, it has been found that, based on safety reports in the aviation domain, 76% of the errors related to SA were because of Level 1 (i.e., failure to correctly perceive information), 20.3% were Level 2 errors (i.e., failure to comprehend the situation), and 3.4% were Level 3 errors (i.e., failure to project situation into the future) (Endsley, 1999; Endsley & Garland, 2000). Hence, this statistical information provides an indication of the relative importance of these three aspects of SA. It has been noted that human error is a significant factor (71%) for accidents in the aviation domain, and among those, 88% of the accidents are directly related to the SA problems (Shuang, Xiaoru, & Damin, 2014). These statistics highlight the importance of understanding SA from a more cognitive perspective.

Furthermore, Endsley has indicated how attention, goals, expectations, mental models, long-term memory, working memory and automaticity contribute to situation assessment in terms of cognitive processes (Endsley, 1995; Endsley, 2000). The following summary from Endsley provides some useful indications of how this definition (through her model) can be related to the neurocognitive literature (presented in section 'Situation awareness related processes viewed neurologically, psychologically and behaviourally'):

> ''*To summarize the key features of SA in this model, a person's SA is restricted by limited attention and working memory capacity. Where they have been developed, long-term memory stores, most likely in the form of schemata and mental models, can largely circumvent these limits by providing for the integration and comprehension of information and the projection of future events (the higher levels of SA), even on the basis of incomplete information and under uncertainty. The use of these models depends on*