Methods for Predicting Human Behaviour in Emergencies: An Analysis of Scientific Literature

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1. Introduction

The increased threat of terrorist event such as the explosion of a dirty bomb in densely populated urban areas necessitates modification of existing frameworks of local response. The primarily goal of first responders is to mitigate the consequence of such a disaster by reducing the number of victims, and securing resources for protection of the general public to avoid further injuries (Civil Contingencies Secretariat, 2005; Great Britain, 2005). This may be successfully accomplished if the incident commanders anticipate the reactions of affected people and the influence of the environment on human reasoning. Therefore, models representing common patterns of spatially aware human behaviour under severe, life threatening conditions, need to be incorporated into the modern emergency response plans and guidelines.

A commonly used technique for modelling human behaviour is the first principles approach (Laughery, 2005). This approach involves identification, typically from literature, of the underlying goals and principles which govern a person's performance. Several hundreds of peer-reviewed studies of behaviour have been conducted to date. These have identified a large number of principles which can be implemented as algorithms in simulation systems. The resulting simulations can subsequently be used to investigate different approaches and response scenarios for first aid and evacuation. The principles are, however, of diverse quality and much effort is required to identify which ones to use. Furthermore, they can be unspecific, un-quantified, or incomplete. For instance spatial behaviour of victims and the effects of the geographical space on human reasoning have been often neglected. This leads to difficulties with verification when used in situations other than those from which they were originally derived (Cornwell et al., 2002; Laughery, 2005; Silverman et al., 2001; Silverman et al., 2006).

Human behaviour can also be predicted through the application of other, less commonly applied, techniques. For example, sequential analysis involves the study of events and their interactions as they unfold over time. The basic method for sequential analysis is to classify behavioural patterns (either live from direct observation, or retrospectively from interview transcripts, CCTV footage, etc.) using a pre-defined taxonomy of behaviours. These data can be relevant when identifying the probability of one particular type of behaviour following another. Furthermore, these analyses enable us to extract generic behaviour patterns which can be easier transformed into simulation models (Bakeman and Gottman, 1986).

Other techniques which may prove suitable for depicting behavioural patterns include activity sampling (Kirwan and Ainsworth, 1992), expert judgements (e.g. Dombroski et al. 2006) and

qualitative analysis of interview data (Kirwan and Ainsworth, 1992). These techniques will be applied and analysed in a series of future studies. This paper reports on the use of the first principles approach for modelling spatial behaviour in a CBRN (chemical, biological, radiological or nuclear) emergency.

2. Method

The first principles approach involved an extensive literature review followed by abstraction of the findings into a conceptual model of human spatial reasoning under extreme conditions. Various journal papers from psychological, sociological and human factors research related to human behaviour in emergencies were reviewed. Issues originating from these research domains have been widely studied from different perspectives, for example behavioural response to a natural disaster (Lachman et al., 1961; Perry and Lindell, 2003; Quarantelli, 1996), crowd dynamics of football supporters (Still, 2000) and the emergence of riots (El Rhalibi and Taleb-Bendiab, 2005).

However, due to the lack of empirical evidence, a thorough investigation of citizens' reactions to a CBRN terrorist incident remains a great challenge. The latest research results presented by Drury (2004) and later followed by Drury and Cocking (2007) indicate occurrence of the same kinds of human behaviour patterns and psychological processes across different scenarios, different kinds of disasters with different populations of survivors. The research presented in this paper inclines towards the belief that people are most likely unable to distinguish between an "ordinary" explosion and a CBRN incident in the first minutes after the blast. It was therefore assumed that the reaction of citizens in the first hour after the explosion will be in both cases the same. This enables the use of findings from research related to any type of sudden, impulsive and location restricted emergency.

3. Results

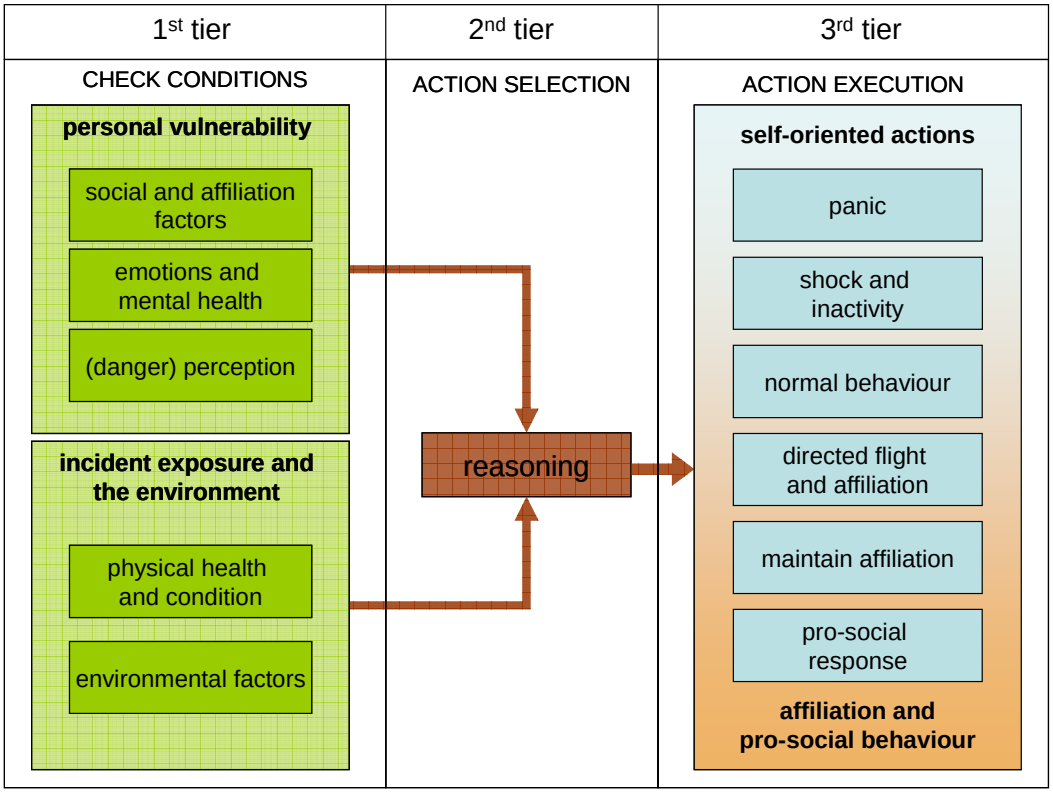

Figure 1. The three-tier agent architecture

The characteristics of human behaviour patterns obtained from the literature survey assisted with the creation of a generic conceptual model depicting the most common citizen's reaction to an urban

CBRN incident and factors contributing to their changes. It is important to mention that the whole spectrum of reviewed articles contributed to the model.

The model defines the action selection mechanism of an individual person, and forms a framework on which a software agent could be designed. The model represents a decision process based upon an assessment of the situation and selection of an appropriate action triggered by external and internal stimuli. The three-tier architecture of the agent is illustrated in Figure 1. The first tier processes the input information. This information is further decomposed according to selected factors having influence over the agent's external behaviour. These factors are either internal, representing the personal vulnerability of the agent and its personal characteristics, or external, specifying the agent's perception of the environment and incident effects. Each of the factors is affected by one or more agent attributes such as gender, energy, social affinity, mobility, etc. The result is then passed into the second tier where the reasoning determines what action to execute. This is the place where all the obtained input is analysed and evaluated against the current values of the agent's attributes. The actual action is performed in the third (output) tier. Further explanations of all the possible behaviours are provided in the Table 1.

Table 1. Characteristics of emergency behaviour

Behaviour	Specification
Panic	- irrationality - bewilderment - hysterical flight - ignorance of the environment
Shock and inactivity	- numbness - no movement
Normal behaviour	- original plan execution - no change in initial behaviour
Directed flight and affiliation	- normal to fast walk towards affiliate factors (family, home, etc.)
Maintain affiliation	- formation of ad-hoc groups - movement in groups - leader following - assisting group members - adapting to group behaviour
Pro-social response	- mutual helping based on social roles - provision of first aid and rescue - self-sacrifice for sake of helping others

4. Discussion

The literature review provided a good opportunity for the collection of diverse research results and critical points of current knowledge of human response to an explosion. There is however an apparent drawback in terms of the information accuracy. Moreover, references to the resources of the findings are often incomplete, twisted or even omitted. This generates a huge uncertainty and possible misunderstanding of the original knowledge. Utilisation of such results as a theoretical basis for the implementation of simulation models may lead to incorrect interpretation of human behaviour, which could in turn produce catastrophic consequences if consulted during the creation of evacuation plans.

The most accurate source of information appear to be direct interviews with disaster survivors or archives containing victims' testimonies, and observation reports. Example of such research can be found in Drury and Cocking (2007), Mawson (2005) and Sime (1999). In order to keep the behaviours in the conceptual model realistic, greater emphasis was put on the literature which draws upon findings from direct contact with victims or consultation of archived reports.

The literature review also revealed various models concentrating on different aspects of the human reaction. For instance Mawson (2005) focuses his attachment model and typology of response on the perceived degree of physical danger and levels of social support available in the situation. Drury and Cocking's (2007) research aim was to understand the conditions under which people start cooperating with each other, despite not knowing each other prior to the emergency. In spite of these differences, the reviewed papers have common themes such as the conclusion that panic, irrational and selfish behaviour are not the most commonly observed reaction of the public as it was believed in the past or as is widely presented in the media (Alexander and Klein, 2006; Mawson, 2005; Sime, 1999).

The spatial aspect of human behaviour has not been widely discussed in the reviewed papers. Still (2000) based his model of crowd movement through space on the assumption that people in a disaster tend to follow path of least effort. He defined such route based on the geometrical representation of the space, e.g. width of the escape routes and their congestions. Johnson Jr. (1985) argues that the initial distance of a person from the location of the incident has strong influences on the selection of egress routes and speed of evacuation. It has been reported that despite the physical nature of the area people tend to evacuate in the direction of their homes or place where their family is located by following well-known paths as oppose to searching for alternative routes (Dymon and Winter 1993; Mawson, 2005; Raphael, 2005).

5. Conclusion

The literature review was sufficient to generate a conceptual model depicting the conditions, action selection and action execution of an agent. The conceptual model has yet to be implemented for agents within a simulation; it is at this stage when other issues associated with the use of literature for modelling human behaviour in agents may become apparent (e.g. creating algorithms from un-quantified or incomplete models, verification difficulties) as well as issues related to the representation and effects of the simulation space on agent's behaviour. The process presented in this paper will be repeated using other methods for describing human behaviour than the first principles approach. The outputs of these models will be analysed for their usefulness as techniques for predicting the human response to emergency situations.

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Biography

Věra Karasová is a PhD student at the Centre for Geospatial Science, University of Nottingham. Her research focuses on issues related to planning and management of response to large urban CBRN incidents. She is particularly interested in application of agent-based modelling into the disaster management domain. She obtained her MSc. at Helsinki University of Technology and her undergraduate degree at Czech Technical University in Prague.

Glyn Lawson in a Research Fellow and Part-Time PhD student at the Human Factors Research Group, University of Nottingham. His research concerns the analysis of methods for predicting human behaviour in emergency situations. He came to the University having previously spent several years working as an Ergonomist in industry.