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## Deliverable D2.1.2 Conceptual Model of Mobile User Interaction in Emergencies 2

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## **Executive Summary**

### **Conceptual Model**

This document presents Deliverable D2.1.2 (Conceptual Model of Mobile User Interaction in Emergencies 2) of the project FP7-614154 | CNPq-490084/2013-3 (RESCUER), a Collaborative Project supported by the European Commission and MCTI/CNPq (Brazil). Full information on this project is available online at <http://www.rescuer-project.org>.

Deliverable D2.1.2 provides the results of Task 2.1 (Mobile User Interaction in Emergency Situations) for the second project iteration. Therefore, it first summarises two main activities performed to investigate human behaviour in emergency situations: a literature review and a series of workshops conducted with workforces on different occasions. Then it presents the current task results. One result is a consolidated human reaction model for emergency situations, which includes the basic phases of information processing: risk identification, risk assessment, and risk reduction. Another result is the definition of a strategy for gathering information from the crowd in emergency situations and the requirements on the user interface. Finally, a set of basic UI guidelines that characterise user needs during interaction with mobile devices in an emergency situation is defined. The UI guidelines are based on the follow principles: simplicity, accuracy, instant usage, error tolerance, and flexibility. These findings provide the foundation for the development of interaction concepts for the RESCUER mobile solution, the so-called Mobile Crowdsourcing Solution.

#### List of Authors

Claudia Nass – Fraunhofer

Dominik Magin – Fraunhofer (1st version)

Kai Breiner – Fraunhofer (2nd version)

Karina Villela – Fraunhofer (1st version)

Eduard Groen – Fraunhofer (2nd version)

#### List of Internal Reviewers

Tobias Franke – DFKI

Laia Pedraza – VOMATEC

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# 1. Introduction

## 1.1. Purpose

The RESCUER project aims at developing a smart and interoperable computer-based solution for supporting emergency and crisis management, with a special focus on incidents in industrial areas and during large-scale events. The RESCUER solution will be composed of four main components, namely Mobile Crowdsourcing Solution, Data Analysis Solutions, Emergency Response Toolkit, and Communication Infrastructure. This deliverable provides the foundation for the development of interaction concepts of the Mobile Crowdsourcing Solution (also called RESCUER app), whose goal is to support civilians, supporting forces and workforces in providing the command centre with information about emergency situations, taking into account the different types of smartphones that might be used and how people interact with them under stress.

The overall goal of RESCUER Task 2.1 (Mobile User Interaction in Emergency Situations) is to derive guidelines for interacting with mobile devices during an emergency or crisis situation. To do so, it is necessary to first understand human reactions in emergency situations, and then to derive requirements and guidelines for developing user interfaces (especially mobile user interfaces) to be used in such situations.

Human reaction in emergency situations has already been studied and simulated [1, 2, 3]. These previous studies form the basis for the ideas described in this deliverable. It is important to determine the impact of emergency situations on human cognitive workload capabilities. Cognitive availability characterises a person’s ability to perceive or deliver information during an emergency situation. Depending on the cognitive consumption of the situation, there is a certain amount of cognitive availability people can afford to spend on interacting with their mobile device. Thus, it is important to know the concrete aspects that cause stress and how they affect the available cognitive capabilities.

In addition to the studies of human reaction in emergency situations, some requirements for user interfaces of emergency and crisis management systems have already been documented in the literature. Based on those references as well as on the findings of the different workshops carried out with workforces, user interface requirements and guidelines have been derived.

## 1.2. Changes Log

This deliverable is used as a working document and will be refined during the different iterations of the RESCUER project.

D2.1.1	Initial draft containing the RESCUER Human Reaction Model, as well as first guidelines based on a literature review and an expert workshop.
D2.1.2	Refinement after analysing how emergencies are detected and processed: <ul style="list-style-type: none"> <li>• Workshop with workforces: Section 2.2</li> <li>• RESCUER Reaction Model, especially regarding reaction changes and motivation: Chapter 2</li> <li>• Interaction Strategies and Requirements: Chapter 4</li> </ul>

### **1.3. Partners' Roles and Contributions**

In the first and second project iterations, Fraunhofer was responsible for the research activities and for creating the deliverable of Task 2.1 (Mobile User Interaction in Emergency Situations). VOMATEC, FireServ, COFIC, and DFKI supported Fraunhofer in preparing and conducting the workshop with the workforces.

### **1.4. Document Overview**

The remainder of this document is structured as follows:

- Chapter 2 contains the theoretical background for human reaction modelling in emergency situations. It describes the workshops conducted to analyse human behaviour in emergency situations, and how emergency situations are detected and processed.
- Chapter 3 presents the RESCUER human reaction model.
- Chapter 4 presents our current interaction modes for communicating with the crowd in emergency situations as a function of both the level of stress and the cognitive abilities of the different target groups within the crowd. Additionally, general user interface guidelines for emergency situations are described.
- Chapter 5 provides the conclusion.

## 2. Human Behaviour Model in Emergency Situations

This chapter contains the literature review on human behaviour models regarding emergency situations as well as the summary information about the workshop conducted together with representatives of the workforces.

### 2.1. Theoretical Background

People in emergency situations act irrationally, start to panic or show antisocial behaviour [1]. Panic is defined as the inability to think clearly while simultaneously having the tendency to frantically run away from buildings or the scene of an incident. Antisocial behaviour is defined as the desire to take advantage of other people in an emergency situation (e.g., stealing possessions or using violence to protect one's own interests). News broadcasts and the media in general have impregnated our minds with this picture. However, recent research has suggested that this kind of reaction is a myth that has no empirical basis. According to McEntire [1], studies and analyses of past emergency situations show that people act rationally and altruistically during and after an emergency situation. They behave calmly and know how to protect themselves and others in their social sphere.

Definition [4]:

An emergency is an **event or situation** which **threatens to inflict serious damage on human welfare** (e.g., loss of human life, illness, injury, homelessness, damage to property, disruption of the supply of money, food, water, systems of communication, facilities for transport, or services relating to health) **or the environment** (e.g., contamination of land, water or air with biological, chemical or radioactive matter, or disruption or destruction of plant life or animal life).

Pan [5] presents a human and social behavioural model for typical emergency situations at large-scale event scenarios that involve overcrowding and crushing, for example at sports stadiums, schools, or social gathering places (e.g., nightclubs). His goal was to build a multi-agent simulation system for egress analysis. He identified typical evacuation behaviours that were modelled in a computational framework – queuing, competitive, leader-following, altruistic and herding behaviour. These behaviours are related to the output of the decision-making process that is responsible for identifying and properly responding to an emergency situation. Factors influencing this process and thereby human behaviour include:

- Human physical characteristics (i.e., body size, mobility, age, and gender)
- Environmental characteristics (i.e., geometric constraints, emergency type, and egress systems)
- Psychological and sociological characteristics (i.e., individual, interaction among individuals, and group)

Gannt & Gannt [6] claim that emergency plans and processes in industrial area scenarios should also be based on typical human cognitive capabilities and behaviours in order to be more efficient. They argue that most emergency plans and systems ignore such human capabilities and, consequently, expose the employees and the environment to higher risks. They paid special attention to the cognitive decision-making process that people execute during emergency situations, environmental changes and social aspects. They argue, based on the Social Attachment Model of

Mawson [7], that social bonds between people involved in an emergency situation are solidified and even newly created.

The basis for all decision-making processes that will be presented below is the approach by Perry and Greene [3]. They describe a decision-making process that is executed by individuals who identify and properly respond to an emergency situation. They characterise human behaviour in a disaster as “non-traditional behaviour in response to a changing or changed environment” [3]. This means that individuals who face unexpected environmental changes re-examine their own behaviour in relation to the new conditions and adapt their behaviour in order to protect themselves and minimise harmful consequences. This process of behaviour adaptation includes three phases: *risk identification*, *risk assessment* and *risk reduction*. In case of an emergency situation, the changes in one’s immediate environment are recognised as a threat to the individual, and the individual takes protective actions accordingly.

Leach [8] explains that the decision-making process is managed in the working memory of humans as a neurocognitive function. The processing of such information involves several steps in order to turn the perception of a risk into an appropriate action. Under optimal conditions, this takes a minimum of eight to ten steps, but this number can increase due to higher task complexity and physiological factors that influence the individual. The processing of an emergency situation often results in “freeze” behaviour of the individual just after he or she has perceived the threat. Leach classified three typical behaviours in response to threats [8]:

- The first group (10–15% of the people involved in an emergency situation) will remain calm, think quickly, and retain situational awareness; their judgement and reasoning abilities remain relatively unimpaired.
- The second group (75% of the people involved) will be stunned and show impaired reasoning and sluggish thinking.
- The third group (10–15% of the people involved) will show confusion, paralysing anxiety, and have counterproductive behaviour that adds to their risk.

In Sections 3.1 and 3.2, the causes and effects of these groups will be explored in more depth.

The term *stress* is frequently used in the context of emergency situations such as disasters. However, stress is a vague term that can have different meanings. Broadly speaking, stress is the human reaction in view of a stressor, which in the case of an emergency situation is the threat.

Definition [9]:

**Stressors** (i.e., what causes stress) are “circumstances that threaten a major goal, including the maintenance of one’s physical integrity or one’s psychological well-being”. The psychological response to a stressor is called **distress**.

*Distress* can be manifested as affective states, such as anxiety, frustration, euphoria or sadness. Kemeny [9] proposes an *integrated specificity model of stress*. In this model, the exposure to a specific stressor shapes an integrated psychobiological response (which includes emotion/motivation and physiological responses) in order to generate a protective action in reaction to the threat. In this model, the resources available for reacting to a threat moderate the relationship between stressor and psychobiological response. This means that the level of stress in view of a threat is regulated by one’s own motivation and physiological responses to the threat, and by the individual’s resources for reacting. Resources, in this case, may include time, tools, abilities and space.

Finally, Staal [10] explores the correlations between stress, cognition and human performance. He addresses the effects of various stressors on cognition. He found that stressors reduce the performance working memory (i.e., the brain area responsible for the decision-making process in emergency situations). Considering that the decision-making process executed in view of a threat in an emergency situation takes place in the working memory, it can be concluded that the level of stress affects the execution of the decision-making process. Thus, the level of stress experienced by a user can diminish his or her cognitive capabilities and performance in the face of a threat.

## 2.2. Workshop with Workforces

In addition to the literature review presented above, a series of workshops with workforces was conducted to elicit more detailed information on human reactions in an emergency situation. This section describes the different workshops performed during the project and their main contribution to the development of the current RESCUER Human Reaction Model.

### 2.2.1. Initial Workshop in Linz, Austria, 2013

In the first workshop in Linz, Austria at the beginning of the project, eight employees of different workforces participated. Table 1 characterises the participants of the workshop based on their function, organisation and work context.

**Table 1: Participants of the initial workshop**

Part.	Function	Organization	Context
1	Regional Rescue Commandant	Red Cross Wels	Large event
2	Police Commandant	Municipal Police of Steyr	Large event
3	Rescue Operation Planner for Large Events	ASB Linz	Large event
4	Department Head - Rescue Command Centre	ASB Linz	Large event
5	Rescue Service Operation Officer, Operation Coordinator	BTF Chemiepark Linz	Industrial
6	Fire Brigade Coordinator	BTF Chemiepark Linz	Industrial
7	Fire Brigade and Rescue Service Operation Officer	FireServ	Industrial
8	Rescue Operation Coordinator	Red Cross Wels	Industrial

During the one-day workshop, the following activities were performed:

1. Identification of stakeholders for large-scale events, including those who are part of the crowd and those who belong to the workforces, using elicitation techniques
2. Identification of the communication flow between the stakeholders
3. Identification of human behavioural patterns in the crowd during emergency situations (for incidents at large-scale events and in industrial areas)
4. Identification of problems related to human reactions (for incidents at large-scale events and in industrial area)
5. Generation of ideas for addressing the identified problems
6. Detailing of the communication flow between the workforces

7. Identification of problems related to communication between the workforces
8. Generation of ideas for supporting command and control centres

The results of the workshop directly impacted the RESCUER Human Reaction Model presented in the next chapter. The main outcomes of the workshop are summarised in Table 2.

**Table 2: Main results of the initial workshop**

<b>Workshop Session</b>	<b>Main Contributions</b>
<b>1. Stakeholders</b>	<ul style="list-style-type: none"> <li>Each organisation uses its own vocabulary for referring to the stakeholders involved in an emergency situation at a large-scale event. However, it was possible to define a common vocabulary.</li> </ul>
<b>2. Communication Flow</b>	<ul style="list-style-type: none"> <li>Identification of the communication flow between stakeholders at large-scale events as well as of the generic information needs of the workforces (i.e., who, what, where).</li> </ul>
<b>3. Human Behaviour Patterns</b>	<ul style="list-style-type: none"> <li>The organisations reported about the emotional state of people facing an emergency situation.</li> <li>In large-scale event scenarios, people do not panic very often. They behave in a very organised and altruistic manner.</li> <li>In an industrial area, most people involved in an emergency situation tend to behave in a process-oriented manner, but their emotional states may vary.</li> <li>The emotional state of individuals varies over time, especially after the arrival of the workforces.</li> </ul>
<b>4. Problems Related to Human Behaviour</b>	<ul style="list-style-type: none"> <li>The biggest problem presented by the organisations was the time spent on providing information and taking care of people involved in an emergency situation. Attending the requests for information from the latter takes precious time away from the workforces.</li> </ul>
<b>5. Solution Ideas for the Mobile Crowdsourcing Solution</b>	<ul style="list-style-type: none"> <li>In large-scale event scenarios, workforces need to get an early overview of the emergency situation, know the crowd's density and moving direction, and dynamically inform people in the crowd about possible actions they can take.</li> <li>In industrial area scenarios, it is important for the workforces to know which actions employees have already undertaken to reduce the impact of the incident, so they can effectively react to the threat.</li> </ul>
<b>6. Organisational Communication Flow</b>	<ul style="list-style-type: none"> <li>Communication between the workforces only occurs at the site of the incident.</li> </ul>
<b>7. Problems Related to Organisational Communication</b>	<ul style="list-style-type: none"> <li>The organisations do not know the operation plans of the other organisations. Different goals, decision-making hierarchies, terminologies and technical systems, as well as the lack of integration among the organisations, are the main aspects that hinder communication.</li> </ul>
<b>8. Solution Ideas for the Emergency Response Toolkit</b>	<ul style="list-style-type: none"> <li>A more collaborative system that allows the organisations to contribute to a common operation plan.</li> </ul>

### 2.2.2. Process Workshop with Workforces and Supporting Forces, 2014

After the first workshop and a first implementation of the initial concepts, a second workshop (Figure 1) was conducted to identify in which part of the process people who are part of the crowd can support the workforces. Table 3 characterises the participants of the workshop based on their function, organisation and work context.

**Table 3: Participants of the process workshop**

Part.	Function	Organization	Context
1	Fire Brigade and Rescue Service Operation Officer	FireServ	Industrial
2	Rescue Service Staff	FireServ	Industrial
3	Emergency Manager	BTF Chemiepark Linz	Industrial
4	Fire Brigade Coordinator	BTF Chemiepark Linz	Industrial

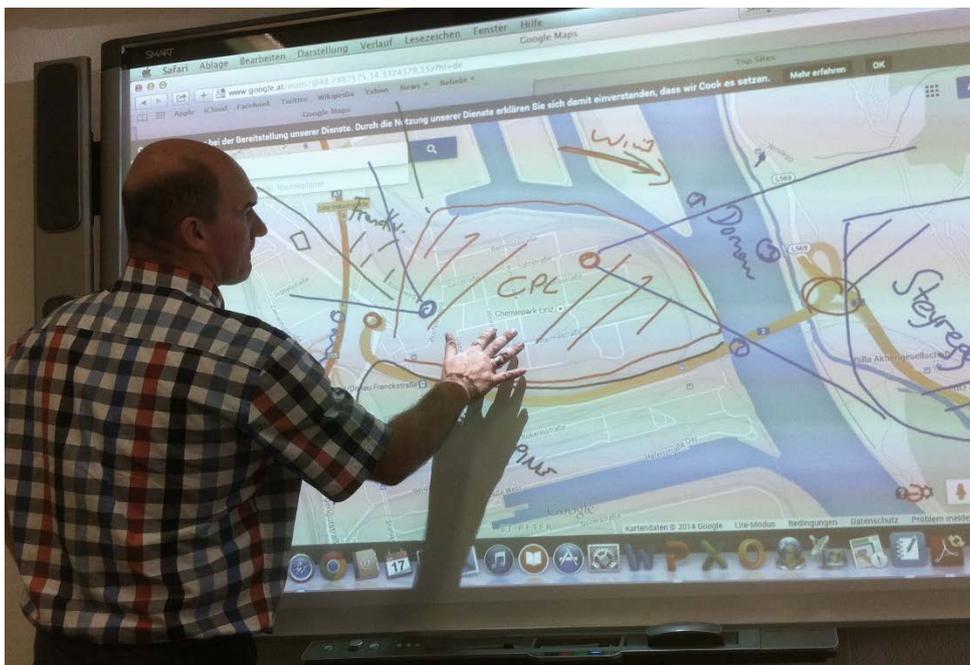
During the two-day workshop, the following activities were performed:

On the first day (focus on industrial context):

1. Identification of activities flow during an incident in the industrial context.
2. Identification of stakeholders involved in the different activities.
3. Identification of information demand in each activity.
4. Identification of activities that present problems during execution and that can be supported by people in the crowd.
5. Generation of ideas to support command centre with the RESCUER app.

On the second day (focus on large events, without the participation of the BTF Chemiepark Linz-Staff):

1. Identification of activities flow during an incident at a large event.
2. Identification of stakeholders involved in the different activities.
3. Identification of information demand in each activity.
4. Identification of activities that present problems during execution and that can be supported by people in the crowd.
5. Generation of ideas to support command centre with the RESCUER app.



**Figure 1: FireServ explaining what effects incidents in the Chemical Park Linz have on the surrounding areas**

The results of the workshop directly impacted the requirements on the user interface of the RESCUER app (presented in Chapters 4 and 5) as well as the features related to the second iteration of the mobile crowdsourcing solution presented in Deliverables D.2.2.2 and D2.3.1. The main outcomes of the workshop are summarised in Table 4.

**Table 4: Main results of the process workshop**

Workshop Session	Main Contributions
<b>1. Process Description</b>	The process identified with the workforces was prepared together with the people responsible for the requirements specification and is currently presented in Deliverable D1.1.2. (Requirements Specification 2).
<b>2. Activities with Improvement Potential</b>	<ul style="list-style-type: none"> <li>• <b>Informing the employees:</b> Currently, the employees of an industrial park are informed via siren followed by speaker announcement, which is difficult to understand and is transitory. Another way of informing the employees in the industrial park is via email. Many employees complain about getting these emails too late or missing them.</li> <li>• <b>Informing the general population:</b> Housing areas near the chemical park are informed, from time to time, about the toxic material that is processed in the industrial park and how to respond to certain incidents. Additionally, in the case of an incident they are informed via siren followed by speaker announcement about protective actions, which is difficult to understand and is transitory, generating anxiety and curiosity in the population.</li> <li>• <b>Obtaining Information from the general population:</b> They lack expert knowledge for describing an emergency situation they have observed.</li> <li>• <b>Catastrophes or environmental hazards:</b> Especially for emergencies that cannot be handled within a few hours but take days or weeks, information from the general population is pivotal in addressing the emergency. If the incident is not restricted to a comparably small area but rather affects an entire city or region, the gathering of information is a difficult task. Traditional communication networks will presumably collapse, demanding a more flexible solution – as the RESCUER project intends to provide.</li> </ul>
<b>3. Feature Ideas</b>	<ul style="list-style-type: none"> <li>• Especially uninvolved employees who might not be directly affected but who need to be evacuated can be informed more effectively and efficiently via the mobile solution.</li> <li>• Neighbours of the industrial park can be easily reached through the RESCUER app and information can be provided in a language that they can understand. They can also be reached when they are not at home, for instance to help them avoid the emergency site.</li> <li>• The general population can contribute by submitting sensory information and impressions that can be interpreted by experts. In this case, the principle “speak the user’s language” is of vital importance for both sides. Experts cannot demand from novices that they describe emergency situations at the same expert level as they could. Novices need to be guided through the reporting process to provide the necessary information that is relevant for the current situation. Both aspects have to be supported by the RESCUER app.</li> <li>• The impact of a standalone mobile app would be rather insignificant in terms of distribution. Integrating the RESCUER mobile solution as an additional functionality within an existing mobile app (e.g., a first-aid app) would be a better solution for the general population.</li> </ul>

### 2.2.3. Variability Workshop EU-Brazil, 2014

The variability workshop took place during the consortium meeting in November 2014 and aimed at identifying the differences between Europe and Brazil in the emergency process in the industrial context as well as in the context of large events. Additionally, it was possible to verify whether there is improvement potential in the Brazilian context as well.

The detailed description of the workshop can be found in Deliverable D 1.4.2 Portability & Variation Management Strategy 2. Table 5 presents the results relevant for the RESCUER app. The information presented below presents additional items compared to the contribution presented in Table 4.

**Table 5: Main results of the variability workshop**

Workshop Session	Main Contributions
<b>1. Process Description</b>	The process identified with the workforces was prepared together with the people responsible for the requirements specification and is currently presented in Deliverable D1.1.2. (Requirements Specification 2).
<b>2. Activities with Improvement Potential</b>	<ul style="list-style-type: none"> <li>• <b>Identification of the incident:</b> Most of the enterprises of the industrial park of Camacari have automatic mechanisms for the identification of an incident (e.g., fire or gas leakage) installed in their production areas. Nevertheless, there are some that do not have identification of such incidents through the use of sensors and depend exclusively on human action for triggering incident alarms.</li> <li>• <b>Getting information and steering supporting forces:</b> The communication system via radio is not efficient for communication between the command centre and the supporting forces located in the neighbourhood of the park. It is very difficult to identify what information the supporting forces are trying to provide and where the information is coming from.</li> </ul>
<b>3. Feature Ideas</b>	<ul style="list-style-type: none"> <li>• Through personalised forms for special situations or enterprises, employees would be able to provide information about details of an incident to the brigade in a standard and easy way.</li> <li>• By using semi-automatic interaction to send structured information associated with the location of the supporting forces, it would be possible to identify where the information is coming from.</li> <li>• Follow-up one-to-one interaction between the command centre and the supporting forces to clarify open questions.</li> </ul>

### 2.2.4. Follow-Up Interaction Workshop Salvador, Brazil, 2014

Finally, a workshop was performed in Salvador, Brazil, in December 2014 to identify the needs and rules for group-target follow-up interaction and, based on that, the requirements on the user interface were derived. Table 6 presents the list of participants in the workshop.

During the one-day workshop, the following activities were performed (focus on industrial context):

1. Presentation of the current status of the RESCUER app.
2. Group-target follow-up interaction vs. Coordination
3. User profile and dynamic group-targeting
4. Mechanisms for group-target follow-up interaction

## 5. Validation of the questions catalogue for follow-up interaction

**Table 6: Participants of the follow-up interaction workshop**

Part.	Function	Organisation	Context
1	Fire Brigade and Rescue Service Operation Officer	FireServ	Industrial
2	Rescue Service Staff	FireServ	Industrial
3	Emergency Manager	BTF Chemiepark Linz	Industrial
4	Fire Brigade Coordinator	BTF Chemiepark Linz	Industrial

The results of the workshop directly impacted the requirements on the user interface of the RESCUER app (presented in Chapters 4 and 5) as well as the features related to the second iteration of the Mobile Crowdsourcing Solution presented in Deliverables D.2.2.2 and D2.3.1. The main outcomes of the workshop are summarised in Table 7.

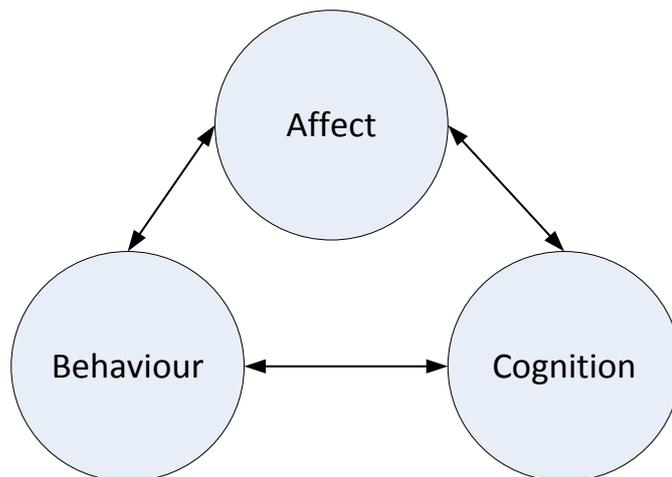
**Table 7: Main results of the follow-up interaction workshop**

Workshop Session	Main Contributions
<b>1. Mechanisms for Group-Target Follow-up Interaction</b>	<ul style="list-style-type: none"> <li>• Interaction with civilians only if they have already interacted with the RESCUER app and are in safety areas, or to find out about their personal status only if they are not moving;</li> <li>• Interaction with supporting forces on site to obtain missing information or investigate potential problems;</li> <li>• Interaction with workforces on site to increase information reliability, obtain missing information, clarify contradictory information or investigate potential problems.</li> </ul>
<b>2. Question Catalogue for Group-Target Follow-up Interaction</b>	<ul style="list-style-type: none"> <li>• A question catalogue was presented and validated together with the participants and is presented in Deliverable 2.3.1 Mechanisms for Group-Target Follow-up Interaction 1.</li> </ul>

### 3. RESCUER Human Reaction Model

The RESCUER Human Reaction Model is based on various models for describing human behaviour in emergency situations, combined with the results of the workshops conducted with the workforces. It is called the “Human Reaction Model” because it defines the human reactions in view of an emergency situation based on affective response, behavioural response and cognitive response [2].

The RESCUER Human Reaction Model uses the ABC Model of Attitudes [11] as a basis for distinguishing between various human characteristics. The model is a simplified representation of what happens within the human organism, separated into three components: affect, behaviour and cognition. The **affect component** describes the emotions that individuals experience during an emergency situation, i.e., **what people feel**. The **behaviour component** presents different behaviours during an emergency situation, i.e., **what people do**. The **cognitive component** presents the decision-making process that people execute during an emergency situation, i.e., **what people think**. As Figure 2 illustrates, these three components influence each other. The result of this interplay characterises the human reactions in view of an emergency situation at a high level of abstraction. In reality, the three components are not as distinguishable because humans are unified organisms with complex internal interrelationships. For example, emotions (affect) do not exist on their own; they are usually the interpretation of a cognitive act (“His words made me angry”) or a cognitive interpretation of the body’s autonomous behaviour (“I notice my hands are trembling; apparently what he said has angered me”). However, distinguishing what is essentially a united system as three integrated components helps us approach human reactions in emergency situations from multiple points of view and beyond the “black-box” approach in which behaviour is the only measurable and perceivable output.



**Figure 2: Interplay between Affect, Behaviour and Cognition**

Figure 3 shows the RESCUER Human Reaction Model. Each of the components will be described in the following sections. We will start with the cognitive component, as this component is responsible for the basal thinking process [11].

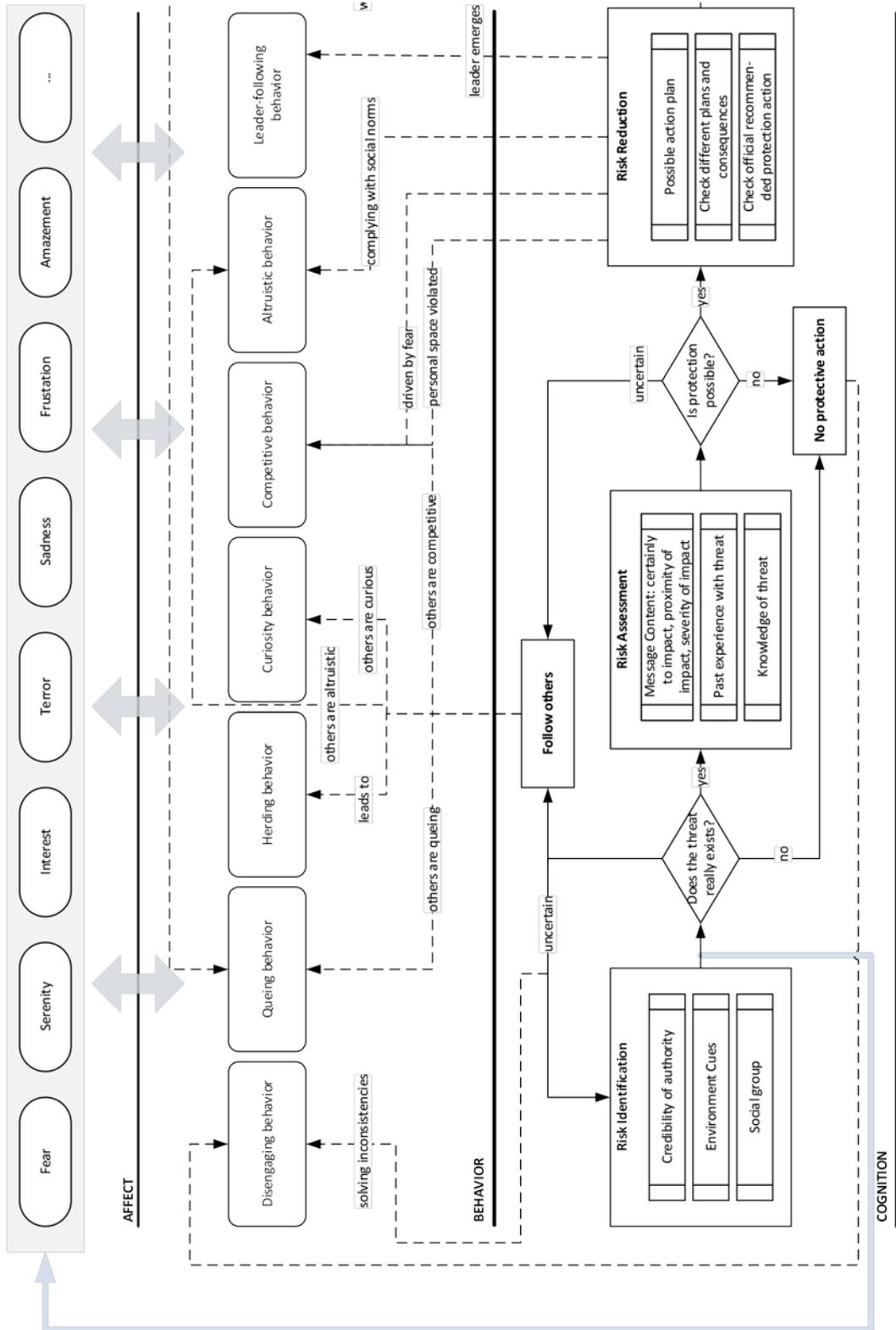


Figure 3: RESCUER Human Reaction Model

### **3.1. Cognitive Component**

The cognitive component represents the decision-making process of people in an emergency situation [3]. This process can be subdivided into three phases: (1) risk identification, (2) risk assessment and (3) risk reduction. It is a cognitive process and takes place in the human working memory [8].

During risk identification, people assess if there is a real threat. Factors that influence this decision are the credibility of the authority that is issuing a warning, environmental cues and the reaction of the social group. In large-scale event scenarios, information coming from authorities (e.g., police or security personnel) is interpreted as being more trustworthy than information from other citizens. Environmental cues are a stimulus for gathering information to select the appropriate response. For example, when hearing a fire alarm, people tend to look for a sign or the smell of smoke or other perceivable indicators of a risk. The third factor is the social group. People look for confirmation that there is a threat by observing the behaviour of other people nearby who are potentially affected. If other people have identified a threat and react accordingly, this will increase people's personal confidence in the severity of the threat. For example, in the case of a fire alarm, employees will observe their colleagues' response. Do they leave the workplace in the direction of a meeting point, or is it a false alarm? If there are inconsistencies between these three factors, people become uncertain and may remain in a closed loop of risk identification until the inconsistencies are resolved. In this uncertain state, people tend to follow others until they are able to recognise the threat for themselves.

If people recognise that the threat is real, they initiate a risk assessment to determine their individual risk [3]. This involves analysing the content of the emergency message, past experiences and their own knowledge about the threat and its expected consequences. The content of emergency messages issued should provide information about the probability of impact, the proximity of impact and the severity of impact. The more detailed the emergency message, the higher its credibility, whereas the more inconsistent or unclear the message, the harder it is for people to assess the real risk [3]. Past experiences with emergency situations may influence the overall assessment positively or negatively. For example, people who have frequently experienced false alarms tend to take alarms less seriously. The third factor influencing the assessment of an emergency situation is previous knowledge about a specific threat. For example, if people are well prepared for evacuating the building in the case of a fire alarm and know what the available resources are for reacting to a fire, they will assess the situation as less severe compared to an emergency situation about which they have no knowledge or for which they have no resources.

Based on the severity level of the emergency situation, people determine their chances of responding to the threat in a particular way. In positive cases, they contemplate different scenarios of how they can reduce their personal risk and/or minimise the impact of the threat. This could also be an official plan, i.e., a plan recommended by authorities in charge of security and safety. Once a potential scenario is selected, the first factor to be considered is the feasibility of executing the plan, among others in terms of available time and resources. People then perform the behaviour that corresponds to the plan they have in mind. People who decide that a reaction is impossible or insufficient do not take any protective action against the threat at a cognitive level.

Besides the conscious cognitive component of responding, the autonomic nervous system also provides an instinctive reflex to ensure self-preservation, known as the "fight-or-flight response"

[26]. Before we discuss in paragraph 3.2 how people behave under such circumstances, this paragraph will conclude with an explanation of why people will normally act, regardless of how rational (e.g., directed protective action) or irrational (e.g., running around frantically) their response is. While the perception of a threat typically leads to a brief “freeze” in the person to better gather sensory information (see paragraph 2.1), the sympathetic nervous system is being activated simultaneously [26]. Hormones and neurotransmitters (including the stress hormone cortisol) are excreted, which cause physiological changes that focus the body’s resources on promoting muscle activity and energy release to optimally mobilise the body and recovery quicker from sustained injuries, while taking away these resources for digestion and sexual activity. The primary response will be to flee, but cognitive functions based on prior knowledge (e.g., training or social norms) may lead to active responses, such as diminishing the threat, managing the situation or helping others. However, biological predispositions, prior trauma or the conclusion that escape is impossible may cause tonic immobility or “fright” [27]. Whereas the “freeze” response is a momentary interruption of activity to allow optimal benefit from the senses, the “fright” response tends to shut out information from the senses and is equivalent to surrendering.

After a “freeze” has occurred in all individuals, the survival mechanism initiated by the autonomic nervous system and mediated by the cognitive processes can result in one of three types of responses: the majority will tend towards “flight”, while a smaller group will “fight” and others will exhibit “fright”, conformant to Leach’s classification [8] discussed in paragraph 2.1. In the behaviour component, these responses will largely determine which type of behaviour is ultimately displayed.

### 3.2. Behaviour Component

This component describes how people act during an emergency situation – what they do. Environmental characteristics influence the action plan chosen by the people involved in an emergency situation. Table 8 presents typical behaviours in emergency situations [5].

**Table 8: Typical behaviours in emergency situations**

<b>Behaviour ID</b>	<b>Behaviour Description</b>
<b>Disengaging Behaviour</b>	Individuals are withdrawn and inactive. They do not look for an exit, adding to both their own risk and that of others, as they block exits and escape ways and interrupt the evacuation flow.
<b>Queuing Behaviour</b>	People self-organise queues to get to the exits; the crowd streams out in an orderly way. Queuing behaviour does not lead to blockages, but to a more effective evacuation.
<b>Herding Behaviour</b>	People evacuate a room through one obstructed exit, while other exits are not fully utilised. This is typical behaviour of individuals who are uncertain about what to do and decide to follow others.
<b>Competitive Behaviour</b>	Individuals compete to exit, violate the personal space of others and do not respect social structures and rules.
<b>Curiosity Behaviour</b>	People move closer to the threat, do not take any protective action, take photos and discuss the situation with other curious individuals. This phenomenon is known as “disaster tourism”.
<b>Altruistic Behaviour</b>	People help other individuals during the evacuation, especially when the

other person is impaired. People observing the willingness of others to help also tend more towards helping. People believe they are following social norms or are being ethical by helping others in difficulty.

**Leader-following Behaviour** People tend to follow others who are higher in the hierarchical group during an evacuation. Sometimes a leader emerges when the situation is uncertain to most people.

The decisions in the cognitive component lead people to display different types of behaviour. Figure 3 presents typical relations between the decision-making process in the cognitive component and the resulting behaviour during an emergency with evacuation in large-scale event scenarios. Particularly when people should evacuate from the site of an incident but encounter inconsistencies while identifying the risk, they may tend to disengage and fail to react to the threat until the inconsistencies are resolved. In the case of high uncertainty, people tend to follow others, exhibiting queuing, flock, or competitive behaviour. If people decide to take protective action, they most likely will follow an assumed leader, e.g., a family member who is deemed to be more rational or an officer of an operational force.

In industrial area scenarios, inconsistencies during the risk identification phase may also lead to people assuming a disengaging behaviour and not reacting to the threat until the inconsistencies are resolved. If people assess the threat as having low severity, they may display curiosity behaviour and approach the threat, endangering themselves if their assessment was wrong. Uncertain people tend to follow others in their competitive, curious or leader-following behaviour, while people acting with certainty will follow their own action plan or the process prescribed by the company. In case there is a deviation from the official action plan, individuals may select a leader to follow, who will usually be a person responsible for safety.

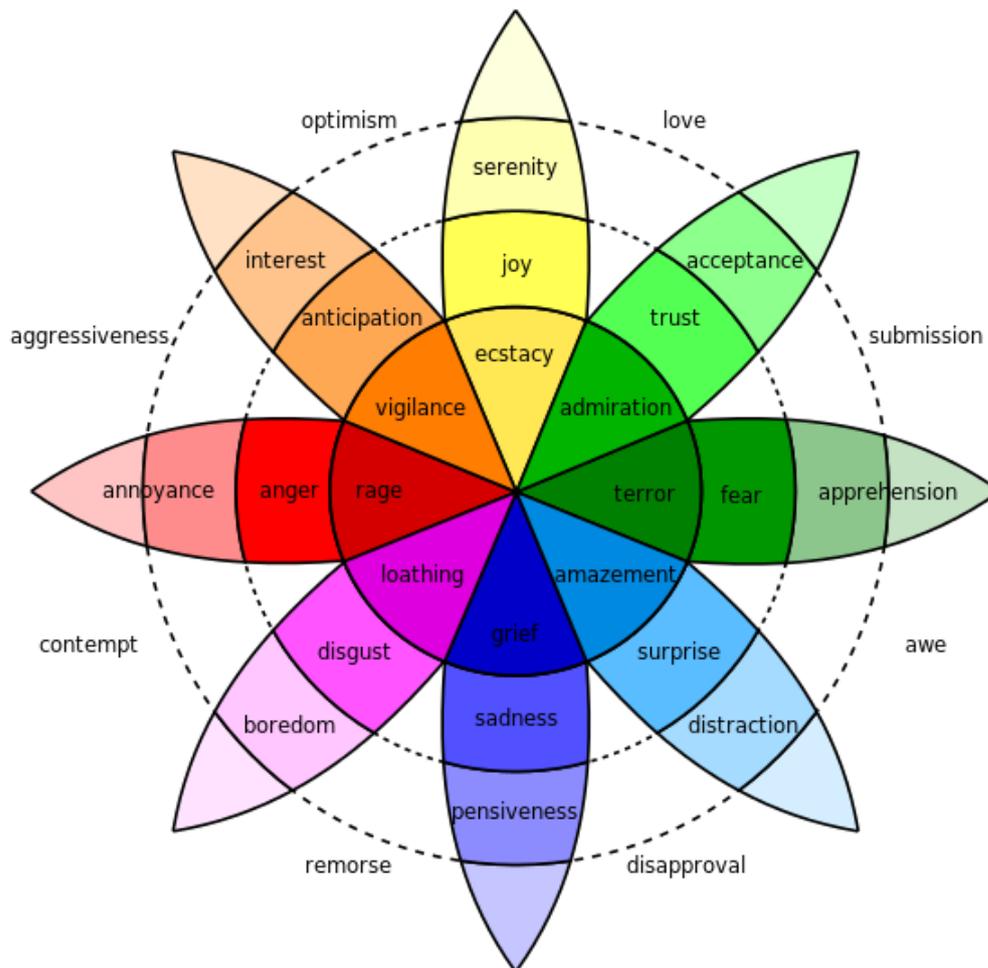
### 3.3. Affect Component

The affect component refers to the emotions triggered during an emergency situation in response to physiological and cognitive factors [11]. Affect describes a person's feelings and their intensity. Plutchik [12] describes eight basic human emotions, consisting of four opposite pairs at different degrees of intensity (see Figure 4).

Negative emotional states are strongly associated with emergency situations in which stress plays an important role (see Section 3.4). Feelings like fear, anxiety, irritability, embarrassment, depression, helplessness, euphoria, frustration and hostility are the most common feelings associated with emergency situations [11]. Some of these typical feelings are associated with certain behaviours, but the direct correlation between specific feelings, behaviour and cognition is very complex and difficult to characterise in detail.

Emotions are one of the most obvious (and best visible) aspects of human reactions. Humans are capable of perceiving the physiological response of others, such as variations in heart rate, respiration and facial expressions, and thereby interpret their emotional state. This, in turn, may influence one's own emotions. This is the reason why human reaction in emergency situations is often described in terms of affect, and it implies that the emotions experienced and observed in a crowd are an important stimulus for determining how to relate to the situation [13]. For example, if

people in the crowd feel anxiety, they show it through their expressions and behaviour, which may influence others who perceive it.



**Figure 4: Emotional states based on Plutchik's emotional wheel [12]**

### **3.4. Reaction Changes, Stress Factors and Interaction Capabilities**

Even when an individual develops a certain reaction in relation to an emergency situation, this reaction is not fixed. The cognitive decision-making process is continuous and capable of adapting quickly. New environmental stimuli are gathered in order to re-assess the severity of the situation and adapt the action plan accordingly. Important factors that influence the assessment of the severity of an emergency situation are:

- **Physical distance** from the threat
- **Elapsed time** since the threat

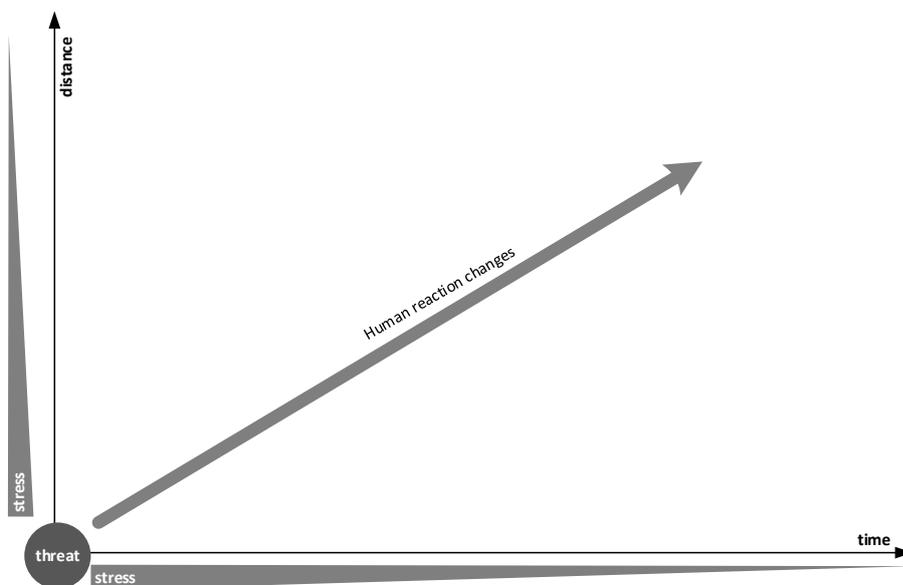
When people increase their distance from the threat, e.g. by fleeing from the site, their behaviour will adapt, as the risk of being directly affected by the threat is perceived to have decreased. Especially directly after exposure to a threat, the experiential system allows for orienting and taking quick, affect-based decisions [23]. When time passes, the situation might be assessed as

less severe, as the analytic system allows for logical and heuristic reasoning [23]. For instance, in response to a fire alarm in an industrial production plant, people will evacuate the plant. Driven by fear, they might just follow a leader, obeying the instructions of the shift supervisor. As soon as they are outside of the plant, the new environmental conditions enable them to consider the event from a process-oriented manner. They will most probably feel calmer and decide that they had best go to the assigned meeting point. The continuous aspect of the cognitive process is illustrated in Figure 5.

Stress also affects human reaction in an emergency situation. According to Staal [10], the definition of stress by McGrath [14] as the interaction between the following three elements includes the most current assumptions about the concept:

- **Perceived demand** is the action plan elaborated by the individual to protect him-/ herself and minimise the threat.
- **Perceived ability to cope with the demand** is the subjective assessment of the resources the individual has available to execute the plan.
- **Perception of the importance of being able to cope with the demand** is the affect-based motivation of the individual to execute the plan and achieve goals.

This definition implies that as long as an individual has the impression that he/she can respond to the stressor with the currently available resources and the internal motivation to do so, the stress level will be low. In Bandura’s social learning theory [25], this concept is known as “self-efficacy”. Conversely, if resources or motivation cannot fulfil the demand, the stress level will be high, and hence, self-efficacy is low. In this context, distance and time affect the three elements that describe stress. The closer an individual is to the threat, the higher his/her level of stress will be. Similarly, right after the occurrence of a threat, the level of stress will be heightened by the individual’s state of uncertainty and anxiety. Figure 5 illustrates the influence of distance and time span on the level of stress.



**Figure 5: Human reaction and stress factors**

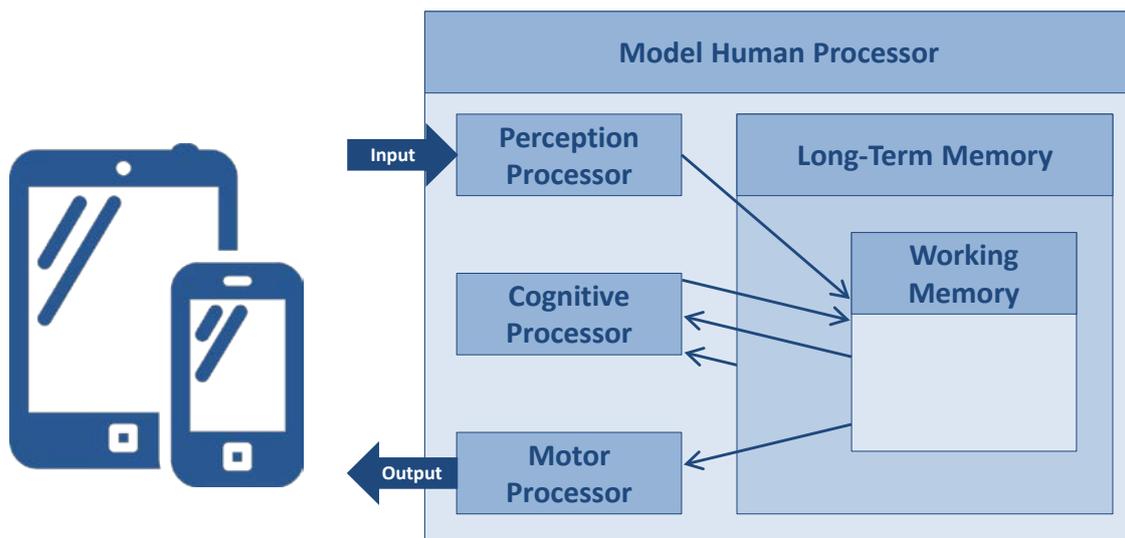
Staal [10] discusses the influence of stress in cognition and human performance, and found that stress, especially in combination with low self-efficacy, impairs working memory, and thus impairs

decision-making (see Section 3.1). The resources available for working memory are reduced under stress, in part due to the physiological changes relating to the fight-or-flight response, consequently also reducing the scope of *attended stimuli*. Particularly affected are points in the process responsible for encoding, rehearsing and retrieving information. This means that individuals are less capable of understanding and recognising information when under stress.

When the stressor is of an emotional nature (e.g., related to a state of anxiety), peripheral events are remembered less often [10] because individuals tend to use as many mentally available resources as possible on solving the primary task. The reduced attention for peripheral events affects the perception and processing of the perceived stimuli, causing changes in the environment that are not directly related to the primary task to be overlooked or to be registered without processing.

Interacting with a software system during an emergency situation also requires focusing attention and deploying resources from the working memory. Figure 6 presents a model human processor, which shows that the processing of information perceived during the interaction with a software system also occurs in the working memory [15], as does the preparation of the motor processor to respond to the stimuli [24]. Breiner [16] describes this interaction process as follows:

“All information that is perceived by a human (stimulus, e.g., visual, auditory, tactile) acts as input for the perception processor. After the execution phase of this processor, the information is available in the working memory. Based on the long-term memory, the information of the working memory is processed by the cognitive memory. The result of this process is again stored in the working memory. The outcome of the human computation in the working memory then triggers the motor processor to execute the desired action (e.g., press a button, make a statement, etc.). Elements of the working memory are linked to the corresponding elements in the long-term memory. Based on previous experience, data and actions that will be executed depending on the content of the working memory are stored in the long-term memory.” ([16], pp. 72–73)



**Figure 6: Model human processor adapted from Card et al. [15]**

The stress level may impair people in their interactions with software systems – in our case a mobile application – because the available resources are being used for the primary task, which is the

decision-making process. Interaction with mobile devices therefore requires the stress level to be sufficiently reduced for sufficient information processing resources to be available.

Conversely, several authors [10] have demonstrated that well-learned tasks tend to be more resistant to the effects of stress. Practice and frequent activation of an operation tend to commit this operation to the long-term memory, which is less susceptible to being influenced by stress. The activation of these memories would allow the user to perform a kind of automaticity, which requires fewer mental resources for executing the task [10]. However, this behaviour is influenced by personality aspects, which will be discussed in Section 3.5.

### **3.5. Motivation and Emergency Situations**

Humans usually identify a threat based on existing knowledge or on the assumption of a risk, but the interpretation and the resulting motivation to act are strongly mediated by the person's current state (cognitively, behaviourally and affectively). While the sympathetic nervous system is primarily working to get the organism itself to safety (see Section 3.1), without conscious effort, the state of an individual is predominantly determined by his or her personality traits. For example, without other factors overriding the personality traits of an aggressive person, he or she will likely be predisposed to displaying competitive behaviour (see Section 3.2). However, conscious effort can steer the behaviour in another direction. For example, a cowardly person can "rise above himself" when compassion drives him to jump through a fire to save a trapped child. Similarly, training can promote desirable actions that may even be counterintuitive (e.g., a neurotic person deciding to remain calm). As this requires a conscious effort on the part of the individual, he or she must have a motivation (i.e., a reason) to spend valuable cognitive resources on steering this behaviour.

Personality traits for a large part determine the extent to which a person will need to be motivated to act differently. The strongest predictive trait in emergency situations is "sensation seeking", which determines the degree to which someone takes risks [28]. The only other personality trait predictive of risk behaviour is high extraversion when it is not moderated by other traits, such as high conscientiousness or low neuroticism [29]. In high-sensation seekers, the regulation of neurotransmitters, enzymes and hormones, among other biological factors, is different from those predisposed to risk aversion. These differences cause them to appraise risky or stressful situations as less to not at all threatening, leading to fewer negative consequences and reduce the time needed to recover compared to low-sensation seekers [28]. Facets of this personality trait include "thrill and adventure seeking", "experience seeking" and "disinhibition", which, among others, explain particular risk taking behaviour, including the choice of hobbies (e.g., skydiving) and professions (e.g., workforces), in which such people expose themselves to particular dangers [28]. As their assessment of a threat evokes less stress, high-sensation seekers are more likely to remain calmer and think more logically in an emergency situation. In addition, their successful performance in previous situations with danger leads to greater perception of self-efficacy [30], further reducing stress while increasing the perceived resources for dealing with the emergency situation and the confidence for taking higher risks. Conversely, for risk-avoidant persons it is much more difficult to execute a clearly structured plan that may put them under greater risk than if they would simply flee.

A person tends to be most motivated to execute a particular action plan composed in a quick decision-making process, which assumes one's personality (a person's "default" way of thinking and

behaving) and intuition in combination with cognitive factors such as knowledge about what to do in a specific situation. Being motivated to interact with the workforces during an emergency situation requires the conviction that this is beneficial to the situation as a whole. If this motivational driver is to be changed, this must be done at a time a person can internalise these motivations, and thus when he or she is not under stress (i.e., not in an emergency situation).

The protection motivation theory [31] analyses how cognitive processes mediate behaviour in response to communication. The theory assumes that if a message evokes fear, the individual is motivated to reduce the resulting unpleasant emotions, preferably through reassuring behavioural advice contained in the information. This can lead to two types of coping behaviour: problem-focused coping or emotion-focused coping [32] (also known as approach versus avoidance [33]). The desired response is problem-focused coping, in which the adaptive behaviour is aimed at controlling the actual threat, usually with the help of learnt or advised behaviour. Emotion-focused coping is maladaptive behaviour, aimed at reducing the emotional threat (i.e., the fear) by avoiding or denying the actual threat [31]. With sufficient self-efficacy, an individual will be motivated to take protective actions. However, maladaptive behaviour may be displayed if a person has low self-efficacy (e.g., uncertainty or lack of confidence), if the execution of the advised behaviour did not lead to a reduction of fear (e.g., because the instructions were too unclear), if the message itself evoked either too much fear (reducing one's self-efficacy) or too little fear (causing the threat's severity or the person's vulnerability to be underestimated) or if the cost of the adaptive behaviour is too high.

### **3.5.1 Motivation and Action Plan**

Motives work on a subconscious level and cannot be formulated by people. Additionally, individual actions cannot always be correlated to the motive, due to the complex interplay of mental and peripheral processes between the motive and the actions taken [34]. Motives are crystallised by a mental decomposition of high-level activities into a sequence of steps or actions. These actions are undertaken in order to achieve one of several sub-goals that together aim to fulfil a particular main goal. Human beings are consciously aware of these goals and the actions taken to attain them, whereas they may be fully unaware of the motives underlying these actions. Norman's [35] seven stages of action assume a breakdown of higher-order intentions and goals into smaller operational parts, which are strongly related to the given conditions in which the action is realised. A person in an emergency situation may act according to a particular plan, unaware that the motives were shaped by prior training. The cognitive processes are, at that particular point in time, not concerned with such forms of self-reflection. Rather, they are aimed to fulfil the goal of dealing with the threat in the best way possible. However, increased self-efficacy and self-confidence and the possession of the required knowledge and tools for shaping or changing these motives may cause the person to respond more appropriately to an emergency.

Activity theory defines a "motive" as the prospective outcome when a certain intrinsic need is fulfilled [34]. Motives drive human activities, i.e., they stimulate and incite people to interact with the world. To influence the motive of persons in an emergency situation thus requires both an understanding of the different needs of this person it should fulfil, and ensuring the salience of these motives. These could be, among others, needs for "reassurance", "survival" or "altruism". To this end, communication serves as a means for receiving reassuring information, while early and targeted



involvement of workforces increases the chances that the hazard can be dealt with quicker and more effectively, thereby making the person feel comforted in knowing that help is on the way and the chances of survival have increased. These feelings are the motives for why a person would spend time interacting with the command centre through the RESCUER app.

In order to lead people to plan interaction with the RESCUER app as a way to fulfil their personal needs, it is also important to understand why people generally participate in crowdsourcing platforms. This is necessary to build the propitious conditions in the context of emergency situations for motivating people to participate. The next section presents concepts that help to understand these relationships.

### **3.5.2 Crowdsourcing and Motivation**

Crowdsourcing is the act of taking a job traditionally performed by a designated agent (such as an employee) and outsourcing it to an undefined and generally large group of people by means of an open call [36]. The concept of crowdsourcing emerged from the conventional concepts of outsourcing, and subsequently OSS Collaboration, Open Innovation and User Innovation in the context of software development [36]. With the introduction of mobile technologies (e.g., smartphones), mobile crowdsourcing arose, enabling increased participation and real-time contributions [36].

In essence, the crowdsourcing mechanism consists of choosing a task or a set of tasks (of an existing business process) that would usually be performed by the staff of the organisation itself and send out an open call to a crowd of individuals, requesting them to perform these tasks on behalf of the company for an agreed compensation [36]. Enterprises will typically outsource those tasks that cannot be performed with internal resources or whose quality could be improved through the participation of the crowd. After individuals in the crowd have completed the tasks, they submit their results to the enterprise for assessment and the enterprise remunerates them for their work. There are variations to this mechanism. For example, the call can be made to a specific group of people or be subdivided into topics. The compensatory scheme can also differ, e.g., rather than simply completing a task, people can also be paid for achieving a predefined level of quality, or only the individual or group with the best result may receive a bounty.

Organisations in non-profit contexts where social empowerment is a key component [37], especially in combination with mobile technology [36], are increasingly applying crowdsourcing. These scenarios face new challenges in terms of how people are motivated to participate in the business process without payment or another extrinsic motivation. In addition, it is a challenge for all crowdsourcing applications to decide in which parts of the process people from the crowd are involved, and in which parts they are not [38]. For example, applied to an emergency situation, the reporting of an incident ideally lies with the crowd, but the subsequent processing and control should be performed by professionals at a command and control centre. The crowd remains involved in the subsequent stages by providing the professionals with invaluable information while receiving clear instructions that they should carry out (e.g., evacuating ground zero through the prescribed exit route). Hence, explained from a traditional crowdsourcing point of view, members of the crowd take on particular roles (reporting, sensing) and perform certain tasks (following instructions from the command centre). The degree to which each individual crowd member is suitable for performing this

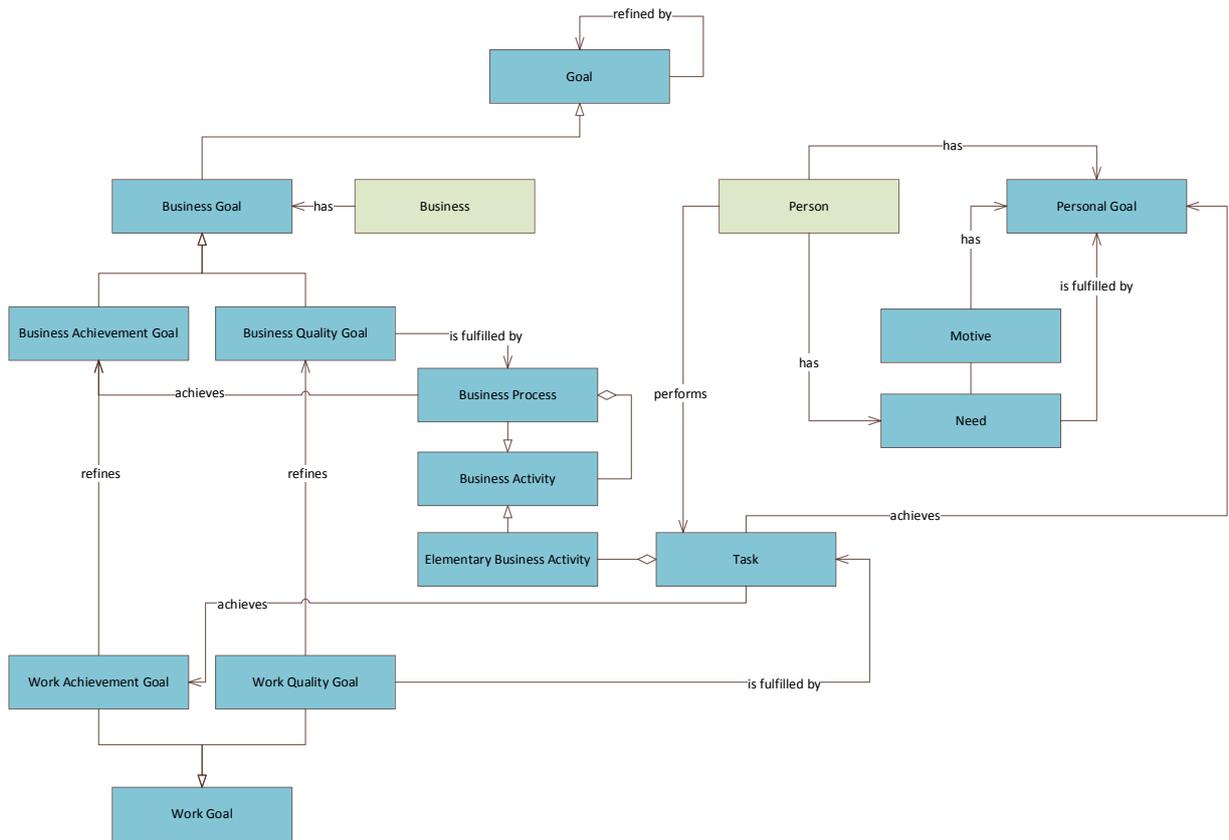
role depends on qualities such as the level of stress, the ability to remain calm and think logically and the person's location with respect to the source of the threat as well as their basic motivation during an emergency situation.

Consequently, the participation of people in the crowd in the business process (e.g., extinguishing a fire during an emergency situation) depends on the basic motivation of the users in using the RESCUER app. Assuming that users are motivated to help the workforces during an emergency situation and that their personal aspects (level of stress, cognitive capability, etc.) enable them to provide this support, the question is: how they can be motivated to choose the RESCUER app to achieve their goals?

Nass et al. [39] investigated how people in a business context can be intrinsically motivated when executing a task related to a business process with the help of a software system. Tasks in business contexts are the most elementary activities performed by people in order to achieve business goals. Figure 7 presents a decomposition of goals in a business context point of view. A goal, in this context, can be a Business Goal (e.g., preventing the building from burning down) or a Personal Goal (e.g., getting to safety). A Business Goal can be decomposed into Business Achievement Goals (e.g., putting out the fire) and Business Quality Goals (e.g., extinguishing the fire fast). A Business Achievement Goal is fulfilled by one or more Business Processes. A Business Process comprises an organisational procedure required to achieve the Business Achievement Goals and can be refined until the Elementary Business Activity (a business activity that can be performed by precisely one role) is complete, which represents one or more Tasks (a personal view on a business activity). The execution of a Task leads to the achievement of a Work Achievement Goal (the refinement of Business Achievement Goals) and the fulfilment of a Work Quality Goal (which describes the properties of and/or the conditions for the performance of a Task).

Nass et al. assume that individuals are motivated in the work context if the Tasks that are performed to achieve a Work Goal also enable the achievement of a Personal Goal [39]. Motives (as explained in subsection 3.5.1) trigger Personal Goals and the achievement of these fulfils their Needs. In terms of our RESCUER app, this means that the task of "providing information" or "following an order" should at the same time fulfil the latent personal needs of an individual in an emergency situation, such as "reassurance", "survival" or "altruism". Particularly when interacting with a software system, the achievement of personal goals can be achieved through concrete system features designed to increase the motivation of people, i.e., by fulfilling their Personal Goals.

The interaction between Business Goals and Personal Goals, as presented in this section, as well as its underlying method for generating motivational features (described in Deliverable D2.3.1 Mechanisms for Group-Target Follow-up Interaction 1) help to identify the features required to motivate people to interact with the RESCUER app in an emergency situation.



**Figure 7: Crowdsourcing and motivation - Balancing business and personal goals**

## 4. Interaction Strategies and Requirements

In this chapter, the overall strategy for coping with cognitive consumption in emergency situations is described.

### 4.1. Emergency Dimensions

Basically, there are two emergency dimensions that influence the way people interact with a software system. On the one hand, there are the time that has elapsed since a threat and the physical distance to a threat, which are responsible for the stress level of an individual (see Section 3.4); on the other hand, there are different target groups at any given site. The following two subsections focus on these two influencing factors.

#### 4.1.1. Stress and Cognitive Capability

Figure 5 depicts the general idea of the level of stress in the face of a threat. It can be assumed that stress during an emergency is based on two factors, which in turn influence an individual's cognitive capabilities:

- **Time span** – As discussed in Section 4.3, the time span between the occurrence of the incident that triggered the emergency situation and the first moment the person is confronted with the situation is a factor that causes stress. The more recent the occurrence of the incident, the less information about the emergency situation is available and the fewer actions have been taken to control the situation. This causes stress because the people at the site of the incident have not had enough time and information to assess the danger and are primarily concerned with protecting themselves and possibly others. With the passing of time, a person is increasingly more capable of gathering information and using reasoning to assess the danger and come up with an action plan for dealing with the situation.
- **Physical distance** – The distance between “ground zero” and the person has a direct impact on the stress level. The closer the victim's position to ground zero, the higher the physical threat (e.g., heat, noise, water). The larger the distance between ground zero and the person, the lower the stress level because the physical threat decreases in the person's perception.

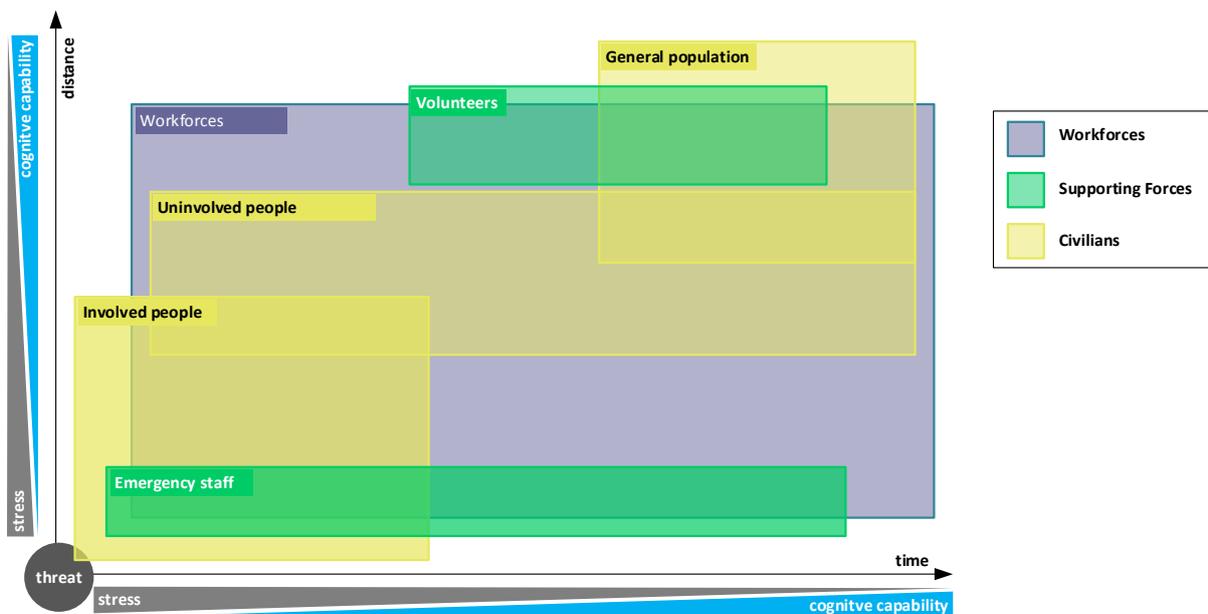
#### 4.1.2. Target Groups

As identified in the second stakeholder workshop (see Section 2.3) and consolidated in the requirements specification, Deliverable D1.1.2 Requirements Specification 2, three basic target groups can be considered for the context of the RESCUER project:

- **Workforces** include the members of the police, the firefighter brigade and the rescue services. They deal with the situation until it has been resolved.
- **Supporting Forces** are civilians who have received special training for dealing with emergency situations. They may actively cooperate with the workforces during an incident.

- **Civilians** include all other stakeholders in the incident, both those who are involved in it and those who are not involved but otherwise affected by it.

Figure 8 depicts the relationships between these dimensions and the identified target groups and stakeholders. Civilians involved in the incident (involved people) are directly at the site of the incident from the beginning on. They will remain in the vicinity of the threat until they are evacuated to a safer distance from ground zero. Uninvolved people, also civilians, are at a greater distance from ground zero and are not aware of the moment the incident took place. The general population (civilians) will be informed after some time and is also at a greater distance from ground zero. Workforces arrive shortly after the incident has happened. They will remain there until the threat is resolved and will guide civilians to a safer location and treat any victims. Emergency staff or security people (supporting forces) will also arrive at the site of the incident shortly after the incident occurred and may help the workforces with domain knowledge where necessary. This suggests that people belonging to the different target groups will tend to interact differently with the RESCUER app based on their cognitive capability at the time of the incident.



**Figure 8: Target group and stakeholders**

## 4.2. Interaction Modes

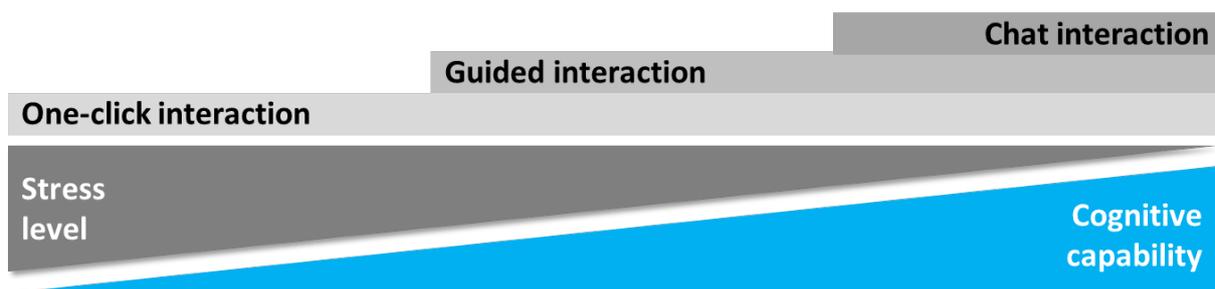
As discussed above, the level of stress in emergency situations has an impact on people’s ability to interact with mobile devices. Therefore, our solution strategy is composed of a spectrum of information gathering in three different modes: one-click interaction, guided interaction and chat interaction. According to our theory, the closer the distance to ground zero and the more recent the incident, the more information has to be gathered automatically. The current characterisation of the three modes is as follows:

- **One-click interaction** – All information that is relevant for the emergency and crisis management system has to be gathered automatically. Since their cognitive capability is

completely consumed by the emergency situation itself, people are unable to respond to any request or complete any task through the user interface. Therefore, any mobile application will have to be able to automatically gather all the information about the situation that is relevant for the workforces. The RESCUER app can automatically collect a lot of highly relevant data from users located in the vicinity of an incident that recently occurred through the physical sensors of mobile devices.

- **Guided interaction** – When people are still not able to respond to complicated interaction demands but can at least provide a little information about the emergency situation, a guided approach ensures that the interaction is kept as simple as possible. These people are likely still near the site of the incident and are too distracted to execute a large set of actions with their mobile devices. Therefore, it is advisable to pose precise questions (e.g., formulated based on the sensor data gathered automatically from the mobile device) and ask them to execute easy and fast actions (such as making multiple-choice selections).
- **Chat interaction** – When eyewitnesses of an emergency situation are safe, they may become observers and can contribute information about the situation more intensively and more actively. Their cognitive workload is no longer fully consumed by the situation, and their ability to interact with their mobile devices the way they usually do has increased. Due to the physical distance and the elapsed time, the information that can be gathered from the physical sensors of the mobile device might not be as important as in the other modes.

Figure 9 depicts the relationship between the available cognitive capabilities and the level of stress in an emergency situation, indicating when each of the aforementioned information-gathering modes is most appropriate. Right after realising the threat, an individual’s level of stress is high, which affects his/her cognitive capabilities. If a person is (or can be assumed to be) under a high level of stress, one-click interaction is recommended. When the stress level has decreased, more cognitive resources become available for guided interaction. When the level of stress is lowered to a level at which the person is capable of interacting with their mobile devices, they can fully interact and provide targeted information through the chat interaction.



**Figure 9: Relationship between stress, cognitive capabilities and interaction modes**

Representatives of the target groups will thus not be pressed into a concrete interaction mode; rather, the spectrum spans an escalation order with three interaction possibilities to approach users in emergency situations. As their cognitive capabilities increase, users are capable of performing more complex interactions. Knowledge of these basic characteristics of the identified target groups within the three dimensions physical distance, time span and target group will be used to derive interaction requirements later on and will impact the interaction design of the mobile solution.

Additionally, we can also assume that civilians directly involved in the incident will probably use the one-click interaction, unlike civilians who are not directly involved in the incident.

### 4.3. User Interface Requirements

Table 9 presents the user interface requirements elaborated in the context of Task 2.1 according to the different interaction modes introduced above.

**Table 9: Strategy-based requirements**

<b>Interaction Mode</b>	<b>UI Requirements</b>
<b>One-Click Interaction</b>	As users are highly impacted by stress or cognitive overload, a single click is the most complex interaction that can be expected. This can be taken as a confirmation of intent, resulting in fully automated information gathering. This means that all mechanisms responsible for gathering data can be activated.
<b>Guided Interaction</b>	As users are not directly impacted by the incident and cognitive workload is available again, more focused interaction can be expected (but not too complex). This can be implemented through simple multiple-choice selection, where the user is guided to a possible answer by being confronted with various answers. By recognising the correct (or most suitable) answer, the user is able to provide more precise information about the incident.
<b>Chat Interaction</b>	Unstructured/open information. Having almost their complete cognitive power available, users can execute more complicated tasks. This means reacting to individually defined tasks or providing a description in plain text. Here, basically all interaction possibilities can be integrated into the app.

### 4.4. General User Interface Design Principles and Guidelines for Emergency Situations

The usage of mobile computing (and its design) in the context of emergency situations is generally “widely under-researched” [17]. In the following sections, we present UI design principles and guidelines for designing mobile applications that should be adhered to in order to enable non-negative user experiences during an emergency situation.

The proposed UI guidelines are based on the following design principles: simplicity, accuracy, instant usage, error tolerance and flexibility, and they assume limited available cognitive workload of the users. These guidelines were derived from the literature review [17, 18, 19, 20, 21, 22] and represent a preliminary set of UI guidelines, (see Table 10). They will be enriched throughout the project, taking into consideration the evolution of the requirements specification of the RESCUER platform (Deliverables D1.1.x).

**Table 10: User interface design principles and guidelines for emergency situations**

Principle	Guideline
<b>Simplicity</b>	The UI is as simple and minimalistic as possible.
<b>Accuracy</b>	All visualisations and the respective possible scales need to be as precise as demanded by the granularity of the information.
<b>Instant Usage</b>	The interaction with the system occurs seamlessly and intuitively. The user knows how to interact with the app without requiring any explanation.
<b>Error Tolerance</b>	The user is prevented from entering wrong input or input that can lead to drastic consequences.
<b>Flexibility</b>	The interaction with the mobile application needs to be designed in a flexible way, one that does not force users into strict interaction paradigms.

#### 4.4.1. Simplicity

When developing mobile applications for emergency situations, designers have to pay “serious attention to the display of information” [18] (i.e., UI design) because inappropriate UIs unnecessarily waste the users’ cognitive workload availability, regardless of whether these users are eyewitnesses or formal responders. As a result, users are either distracted more than they should be when using the improperly designed mobile application, or they just stop using it. Thus, it is important for the UI to be as simple and minimalistic as possible, and to make it intuitive to use [19]. Examples are:

- No unnecessary information: only the information relevant for the situation at hand should be displayed.
- Texts must be short and the language used must be precise in order to avoid misunderstandings.

#### 4.4.2. Accuracy

Since human lives are at stake and any wrong decision may lead to injuries or death that could be prevented, all information provided to eyewitnesses or formal responders must be accurate and therefore represent the current status of the emergency situation [20].

One measure that can improve accuracy in a software system is the validation of data before they are processed. In this way, at least some deviations can be avoided [21].

Not only the data themselves need to be accurate, but also the way they are presented to the user. Thus, all visualisations and the respective possible scales need to be as accurate as the granularity of the information demands. The system state as a whole needs to represent the current state of the emergency situation.

#### 4.4.3. Instant Usage

In an emergency situation, every second counts. Therefore, emergency management systems cannot afford to waste time. This has implications on different levels:

- No training should be necessary for interacting with the RESCUER app. Users should be able to understand the system intuitively. The need for training would mean that the system allows users to enter wrong input, which would be in conflict with the next guideline.

- No upfront process should be necessary to start the mobile application for emergency situations. This means that any additional process (such as registration, login, etc.) has to be optional and the software has to be usable from the beginning.

From the point of view of the people visiting a large-scale event or visiting/working in an industrial area, the mobile application can either be activated by launching it (user-initiated), or a push notification can be sent to the user (proactively, based on location) after an emergency situation has been detected and the user can then launch the application. However, the latter option requires the user to have previously authorised the app to send push notifications.

#### **4.4.4. Error Tolerance**

The user must be protected from entering wrong input or input that may lead to dramatic consequences [19, 21].

For example, if the user is prompted to provide a certain numeric input, it should only be possible to enter input within the valid and expected range. The entering of values that may corrupt the system state is to be precluded.

Once the user brings the system into an undesirable system state, this should be communicated to the user in an understandable way, along with a proposal for dealing with this situation. However, undesirable system states should be prevented in emergency situations altogether. In order to avoid operating errors in the first place, it is important to understand them. Factors that have an impact on those errors can be clustered according to three dimensions [22]:

- **User / personal factors:** general ability, knowledge of the domain, skill / task knowledge training, judgement / decision making, concentration / accuracy and motivation
- **Task / domain factors:** high volume, complexity, repetitiveness, interruptions, time pressure and multitasking / task switching
- **Environmental factors:** temperature too high/low, excessive humidity, poor visibility, high noise levels, excessive vibration, dust and dirt.

#### **4.4.5. Flexibility**

Since people in emergency situations are facing a situation that already consumes large parts of their cognitive resources, they do not want to spend additional effort on adhering to inflexible workflows or following complicated interaction schemes. Therefore, the interaction with the mobile application needs to be designed flexibly, in a way that does not force users into strict interaction paradigms. Instead, the user interface has to allow for multiple types of information and interaction modes, in accordance with what people in an emergency situation want. As a consequence, the interaction design has to contain as few constraints as possible regarding the interaction concept. Examples of measures that can be introduced to provide flexibility are:

- Accept incomplete input, i.e., do not force the user to complete a form.
- Do not reject unstructured information.
- Adapt to the new situation when the user does not react as requested (e.g., when he/she moves in the wrong direction).

## 5. Conclusion and Next Steps

In this deliverable, we propose a Human Reaction Model concerning emergency situations that was created based on a literature review and the series of workshops that took place during the project. The general purpose of modelling human reaction in an emergency situation was to understand how people's cognitive capabilities are affected in such situations. This understanding is essential for determining how people in a crowd can interact with their mobile devices to support emergency handling.

The Human Reaction Model has three components: the affect component captures what people feel, the behaviour component captures what people do and the cognition component captures what people think. The level of stress is one of the other relevant factors influencing the available cognitive capability, which is in turn influenced by the physical distance from the site of an incident and the time span since its occurrence. Based on this understanding, we proposed a strategy composed of three modes of information gathering that consider people's available cognitive capability in emergency situations. The three modes are: one-click interaction, guided interaction and chat interaction.

The requirements on the user interface derived from these three interaction modes were integrated into the specification of the RESCUER app described in Deliverable D2.2.2 Crowdsourcing Information Gathering 2. The prototype developed in Task 2.2 (Crowdsourcing Information Gathering 2) was also used in a study performed in December 2014 and January 2015. The main goal of this study was to validate the underlying theory presented in the current deliverable, i.e., we wanted to investigate whether the requirements on the user interface support the user when interacting with the RESCUER app under stress with low cognitive capability. In this study, 28 participants used the RESCUER app in two different modes: with full cognitive capability and with limited cognitive capability (simulating the use of the RESCUER app under stress). Preliminary results show that the current requirements support user interaction with the RESCUER app in a simulated stressful situation. A complete description of the study and the results will be included in the next version of the current deliverable (D2.1.3).

Additionally, we introduced the concept of motivation in the context of emergencies and crowd. Motivation plays an important role in emergency situations because it influences how people plan their actions in such situations and also determine, among other things, whether they will interact with the RESCUER app. This means that people might use the RESCUER app to achieve a personal goal (e.g., helping others) and not necessarily to help workforces directly.

As shown in this deliverable, the different modes address different target groups with different cognitive capabilities. As a consequence, the mode supports the respective target group and the modes implicitly form an escalation hierarchy in which interaction can be clustered regarding the target groups but also the two dimensions (time and space) related to the incident. Based on this information, basic user interface requirements were derived that will impact the interaction design, which will be described in Deliverables D2.2.2 and D2.3.1.

Furthermore, basic guidelines for enhancing the usability and user experience of mobile applications in order to support emergency and crisis management from the viewpoint of eyewitnesses and formal responders at the site of an incident were defined. These guidelines are simplicity, accuracy, instant usage, error tolerance and flexibility. The findings described in this deliverable are the foundation for the development of the mobile interaction of the RESCUER



platform concerning information gathering, which is part of its Mobile Crowdsourcing Solution component. The provision of more details in terms of follow-up interaction between crowd and command centre as well as crowd steering by the command centre will be the subject of the next version of this document.

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## Glossary

### Terms

**Accident** Undesirable or unfortunate happening that occurs unintentionally and usually results in harm, injury, damage or loss.

**Attended Stimuli** Specific objects in the environment on which someone's attention is focused.

**Command and Control Centre** Group of people assigned to evaluate risks and make decisions in an emergency and/or crisis in an industrial area or at a large-scale event.

**Communication Infrastructure** Component of the RESCUER platform whose goal is to support the information flow between the crowd and the command centre.

**Crisis** Situation caused by adverse and therefore undesired consequences of an emergency situation.

**Data Analysis Solutions** Component of the RESCUER platform whose goals are: 1) fusing similar data coming from different eyewitnesses, 2) analysing photos, videos, and text messages in order to extract information such as the type of incident, the position and dimensions of the affected area, people density, surrounding sources of further danger, evacuation routes and possible approach routes for the formal responders.

**Emergency** An event or situation which threatens to inflict serious damage to human welfare (e.g., loss of human life, illness, injury, homelessness, damage to property; disruption of a supply of money, food, water, systems of communication, facilities for transport or services relating to health) or the environment (e.g., contamination of land, water or air with biological, chemical or radioactive matter, or disruption or destruction of plant life or animal life).

**Emergency Response Toolkit** Component of the RESCUER platform whose goals are to: 1) get contextual information about the emergency, 2) ask eyewitnesses and formal responders for relevant missing information, 3) give instructions to eyewitnesses, first responders and potentially affected people or companies and 4) communicate the emergency to the press, public authorities and the general public in a context-aware way.

**Eyewitnesses** People at the place of the incident who witnessed the emergency situation. First responders are also eyewitnesses.

**First Responders** People at the place of the incident who act to protect themselves and other individuals as well as to minimise the consequences of the emergency situation.

**Formal Responders** Members of the workforces or volunteers who are sent to the place of the incident in order to handle the emergency and restore safe conditions.

**Incident** Can cause damages to life and property and seriously affect the image of a business and/or a country. The concept of incident as defined here includes the concept of accident.

**Mobile Crowdsourcing Solution** Component of the RESCUER platform whose goal is to support eyewitnesses and formal responders in providing the command and control centre with information about an emergency situation, taking into account the different mobile devices that might be used and how people interact with them under stress.

### Abbreviations

**UI** User Interface

**UX** User Experience