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Deliverable D2.1.1
Conceptual Model of Mobile User Interaction in Emergencies 1

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PP	Restricted to other program participants (including Commission Services)	
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Executive Summary

Conceptual Model

This document presents deliverable D2.1.1 (Conceptual Model of Mobile User Interaction in Emergencies 1) of 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 D2.1.1 provides the results of Task 2.1 (Mobile User Interaction in Emergency Situations) for the first project iteration. Therefore, it first summarizes two main activities performed to investigate human behaviour in emergency situations: a literature review and a workshop conducted with operational forces on 3 December 2013 in Linz, Austria. 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. 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: 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.

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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 on large-scale events. The RESCUER solution will be composed of four main components, namely Mobile Crowd Sourcing 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, whose goal is to support eyewitnesses (including first responders) and formal responders 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 smartphones under stress.

The overall goal of RESCUER task 2.1 (Mobile User Interaction in Emergency Situations) is to derive guidelines for interaction with mobile devices during an emergency or crisis situation. To do so, it is necessary to first understand human reaction in emergency situations and then to derive 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 the 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 a user can afford to spend on interacting with his/her 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 a workshop carried out with operational forces in Linz, Austria, user interfaces guidelines have been derived.

1.2. Partners' Roles and Contributions

In the first project iteration, Fraunhofer was responsible for the research activities and for writing the deliverable of Task 2.1 (Mobile User Interaction in Emergency Situations). VOMATEC, FireServ, and DFKI supported Fraunhofer in preparing and conducting the workshop with the operational forces in Linz, Austria.

1.3. Document Overview

The remainder of this document is structured as follows:

- Chapter 2 contains the theoretical background for human reaction modelling in emergency situations and describes the workshop conducted to analyse human behaviour in emergency situations.
- Chapter 3 presents the RESCUER human reaction model.
- Chapter 4 provides our current strategy for gathering information from the crowd in emergency situations as a function between the level of stress and the cognitive abilities of the people in the crowd.
- Chapter 5 describes the user interface and user experience guidelines derived from the RESCUER human reaction.
- Chapter 6 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 operational forces.

2.1. Theoretical Background

People in emergency situations act irrationally, get in panic or show antisocial behaviour [1]. Panic is defined as the inability to think clearly while simultaneously having the tendency to run frantically away from buildings or from the scene of an incident. Antisocial behaviour is interpreted as the desire to take advantage of other people in an emergency situation (e.g., stealing things or using violence to protect one's own interests). News broadcastings and the media in general have impregnated our minds with this picture. However, current research indicates that this kind of reaction is a myth created without any empirical basis. McEntire [1] states that 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 behave to protect themselves and others of their social sphere.

Definition [4]:

> An emergency is an **event or situation** which **threatens serious damage to the human welfare** (e.g., loss of human life, illness, injury, homelessness, damage of property, disruption of a supply of money, food, water, system of communication, facilities for transport, 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 behaviour model for typical emergency situations involving overcrowding and crushing in the scenario of large-scale events. Examples are sport stadiums, schools, social gathering places (e.g., nightclubs) and similar facilities. The 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 typical 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, as a consequence, 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 behaviour in order to be more efficient. They argue that most emergency plans and systems ignore such human capabilities and, as a consequence, increase the risks to employees and to the environment. 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 bounds between people involved in an emergency situation are solidified and even created.

The basis for all decision-making processes presented below is the approach by Perry and Greene [3]. They present a decision-making process executed by individuals when identifying and properly responding 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 environmental changes are recognised as a threat to the individual, and in this case the individual takes protective actions.

Leach [8] explains that the decision-making process is managed in the working memory of humans in terms of a neurocognitive function. Processing such information involves several steps between perception and appropriate action. Under optimal conditions, this takes a minimum of 8-10 steps for completion. However, in an emergency situation the number of steps can increase according to the complexity of the task and physiological factors influencing the individual. The response time spent processing an emergency situation often results in a "freeze" behaviour of the individual just after he or she perceives the threat represented by the emergency situation. Leach classified three typical behaviours in response to threats [8]:

- The first group (between 10-15 % of the people involved in an emergency situation) will remain calm, think quickly, and be aware of the situation; their judgement and reasoning abilities will 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 a counterproductive behaviour that adds to their danger.

The term *stress* is frequently used in the context of emergency situations such as disasters. However, stress is a vague term that can be used with 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 (causing 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 of the organism) in order to generate a protective action in reaction to the threat. In this model, the resources available for reacting to the 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 available resources that the individual possesses for the reaction. Resources, in this case, may include time, tools, abilities, space, and others.

Finally, Staal [10] explores the correlations between stress, cognition, and human performance. He addresses the effects of various stressors on cognition. Exploring the effects of stress on the working memory (i.e., the area responsible for the decision-making process in emergency situations), he points out that stressors reduce the performance of the working memory. Considering that the decision-making process executed in view of a threat in an emergency situation occurs 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/her cognition capabilities and his/her performance when facing a threat.

2.2. Workshop with Operational Forces

In addition to the literature review presented above, a workshop with operational forces was conducted to elicit more detailed information on human reactions in an emergency situation. Eight employees of different operational forces participated in the workshop in Linz, Austria. Table 1 characterises the participants of the workshop based on their function, organisation, and context of work.

Table 1: Participants of the 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

The workshop lasted one day and was organised along the following sections:

1. Elicitation of stakeholders for large-scale events, which included those who are part of the crowd and those who belong to the operational forces
2. Identification of the communication flow between the stakeholders

3. Identification of human behaviour patterns in the crowd during emergency situations (large-scale events and industrial area)
4. Identification of problems related to human reactions (large-scale events and industrial area)
5. Generation of ideas for addressing the identified problems
6. Detailing of the communication flow between the operational forces
7. Identification of problems related to communication between the operational forces
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 workshop with the operational forces

Workshop Section	Contributions
1. Stakeholders	• 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.
2. Communication Flow	• Identification of the communication flow between stakeholders at large-scale events as well as of the generic information needs of the operational forces (i.e., who, what, where).
3. Human Behaviour Patterns	• The organisations reported about the emotional state of people facing an emergency situation. • In large-scale event scenarios, people do not panic very often. They behave in a very organised and altruistic manner. • In an industrial area, most people involved in an emergency situation tend to behave in a process-oriented manner, but their emotional state may vary. • The emotional state of people varies over time, especially after the arrival of the operational forces.
4. Problems Related to Human Behaviour	• 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 operational forces.
5. Solution Ideas for the Crowdsourcing Mobile Solution	• In industrial area scenarios, it is important for the operational forces to know the actions already taken by employees to reduce the impact of the incident in order to effectively react to the threat. • In large-scale event scenarios, operational forces need to get an early overview of the emergency situation, to know crowd density and moving direction, and to inform people in real time about possible actions.
6. Organisational Communication Flow	• Communication between the operational forces only occurs at the site of the incident.
7. Problems Related to Organisational Communication	• The organisations do not know about the operation plan 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.
8. Solution Ideas for the Emergency Response Toolkit	• A more collaborative system that allows the different organisations to contribute to a common operation plan.

3. RESCUER Human Reaction Model

The RESCUER Human Reaction Model is based on different available models for emergency situations and on the results of the workshop conducted with the operational forces. It is called 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].

In this regard, the RESCUER Human Reaction Model presents three components, namely the affect, behaviour, and cognitive components. The **affect component** describes the emotions that individuals feel 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 illustrated in Figure 1, these three components influence each other, and the result of this interplay characterises the human reactions in view of an emergency situation.

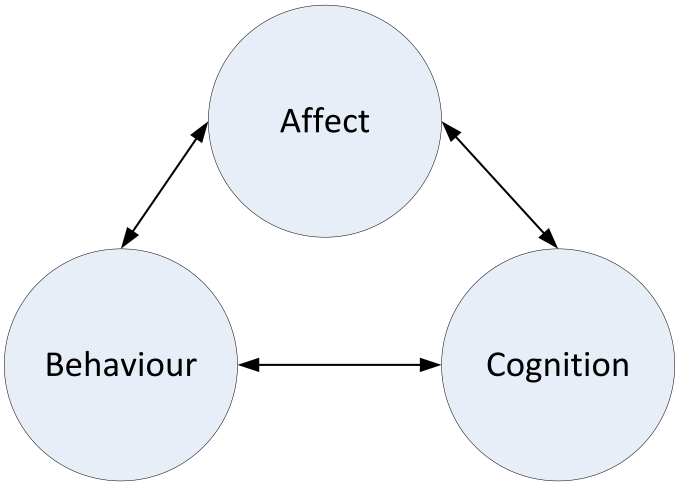

Figure 1: Interplay between Affect, Behaviour, and Cognition

Figure 2 and Figure 3 show the instanced version of the RESCUER Human Reaction Model for the specific application scenarios considered in the project, namely the scenarios of incidents during large-scale events and in industrial areas. Each of the components as well as the specific scenarios is described in the following sections. We start with the description of the cognitive component because this component is responsible for the basal thinking process [11].

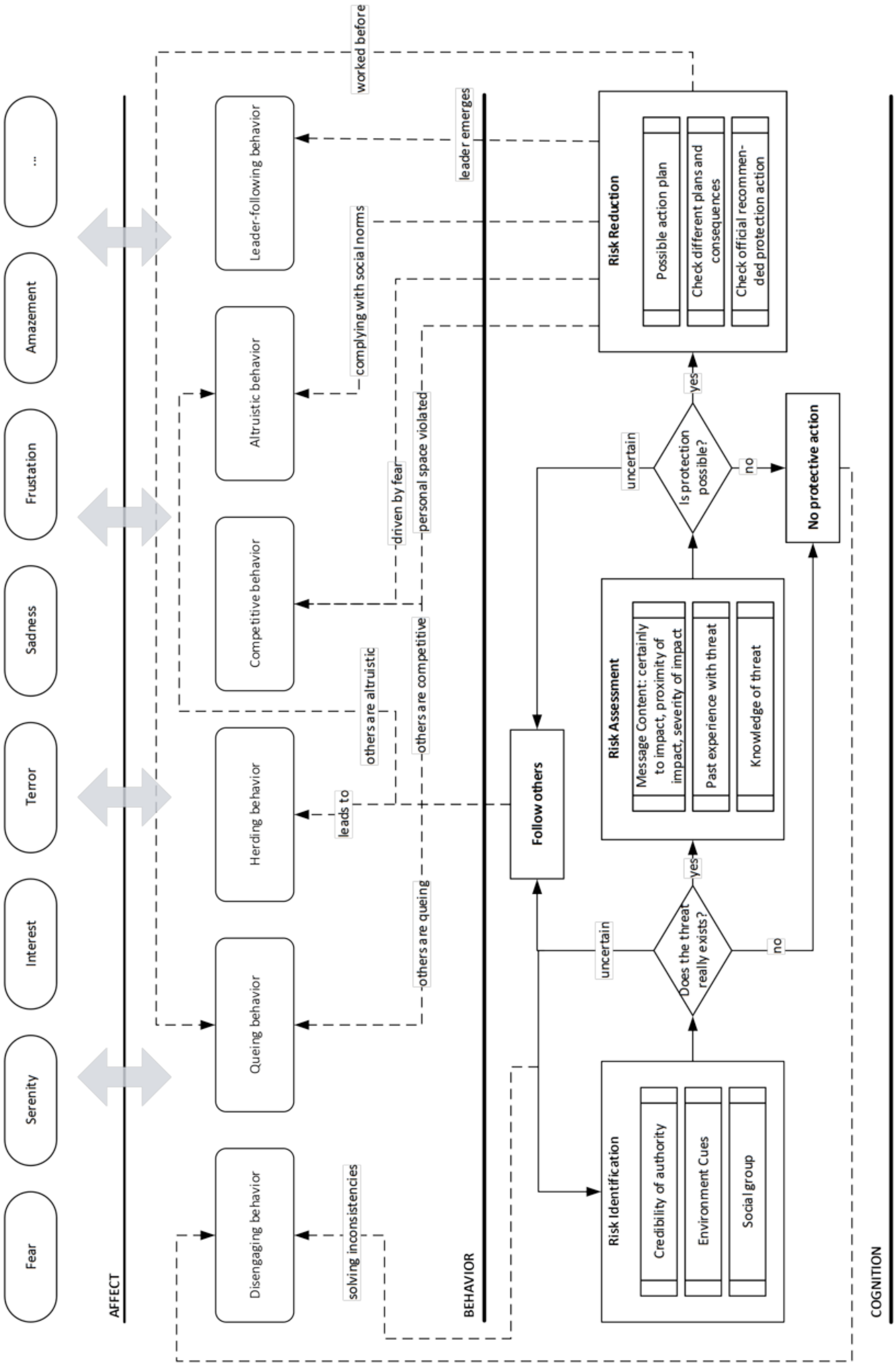

Figure 2: RESCUER Human Reaction Model for large-scale events

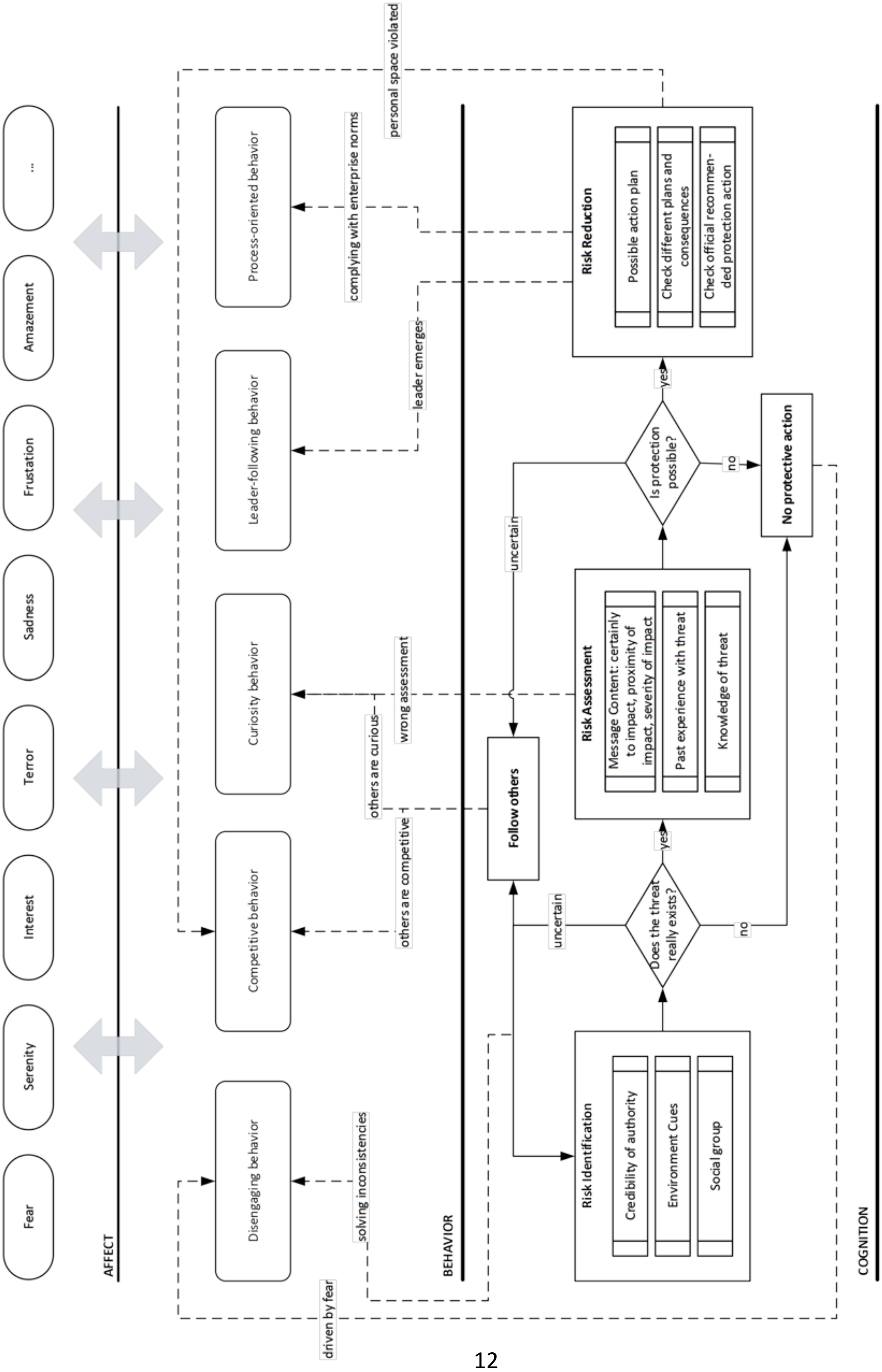

Figure 3: RESCUER Human Reaction Model for industrial areas

3.1. Cognitive Component

The cognitive component presents the decision-making process mentally executed by people confronted with an emergency situation [3]. As already mentioned, this process mainly consists of 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 try to recognise if there is a real threat. Influencing factors are the credibility of the authority, environmental cues, and the reaction of the social group. In large-scale event scenarios, information coming from authorities (e.g., police or security personal) is interpreted as more trustable compared to information coming from other citizens. Environmental cues are also a key factor during the identification of risks, e.g., when they hear a fire alarm, people tend to look for a sign or smell of smoke (perceivable indicators). The third factor is the social group in which people are immersed; they look for confirmation of the threat in the behaviour of nearby potentially affected people. If those other people identify the threat and react accordingly, e.g., if in case of a fire alarm all colleagues start leaving the work place in the direction of a meeting point, observing these individuals will increase personal confidence in the severity of the threat. In the case of inconsistencies between these three factors, people become uncertain and may engage in a closed loop of risk identification when trying to solve the inconsistencies. In an 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 in order to determine their individual risk and the consequences for themselves [3]. This involves analysing the content of the emergency message, past experiences, and their own knowledge about the threat. The content of the message 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. Furthermore, emergency messages with inconsistent or unclear information make it difficult for people to assess the real risk [3]. Past experiences with similar emergency situations also influence people’s assessment of the current situation. This may be positive or negative for the overall assessment. For example, people experiencing frequent false alarms tend to not take alarms seriously anymore. The third factor that influences 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 do not possess previous information.

Based on the severity level of the emergency situation, people determine their chances of reacting to the threat. In positive cases, they start checking different plans in order to reduce their personal risk and/or minimise the impact of the threat. The first factor to be considered is the possibility of executing the plan. People start checking, e.g., if there is enough time and/or resources available to execute the plan. The official plan, i.e., the plan recommended by the authorities in charge of security and safety in a specific scenario, is also checked. After choosing a plan, people assume the behaviour corresponding to the plan they have in mind. If people decide that no reaction is possible, they do not take any protective action against the threat.

3.2. Behaviour Component

This component describes how people act during an emergency situation – what they do. As environmental characteristics influence the action plan chosen by the people involved in an emergency situation, specific emergency scenarios will lead to specific behaviours. In large-scale event scenarios, evacuation is the most typical protective action. Table 3 presents typical evacuation behaviours in large-scale event scenarios [5].

Table 3: Typical behaviours in large-scale event scenarios

Behaviour ID	Behaviour Description
Disengaging behaviour	Individuals are withdrawn and inactive. They do not look for an exit, which adds to their risk and the risk for others by blocking exits and interrupting the evacuation flow.
Queuing behaviour	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 more effective evacuation.
Herding behaviour	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.
Competitive behaviour	Individuals compete to exit, violate the personal space of others, and do not respect social structures and rules.
Altruistic behaviour	People help other impaired individuals during the evacuation. If someone observes that other individuals are willing to help, they also tend towards helping. People believe they are following social norms or are being ethical by helping others in difficulty.
Leader following behaviour	During an evacuation people tend to follow people who are higher in the hierarchical group. Sometimes a leader emerges when the situation is uncertain to most people.

In industrial area scenarios, however, explosion and fluid leaks are the most typical emergency situations. Table 4 describes typical behaviour in this scenario. Its contents were inspired by the previous table and the findings of the workshop conducted with the operational forces in Linz, Austria.

Table 4: Typical behaviours in industrial area scenarios

Behaviour ID	Behaviour Description
Disengaging behaviour	Individuals are withdrawn and inactive, which adds to their own risk and the risk for others.
Curiosity behaviour	Individuals move closer to the threat, do not take any protective action, take photos and discuss the situation with other curious individuals.
Competitive behaviour	Individuals compete with each other, violate the personal space of others, and do not respect social structures and rules.
Leader following behaviour	During an evacuation people tend to follow people who are higher in the hierarchy of the company. Sometimes a leader emerges when the situation is uncertain to most people.

Process-oriented behaviour	People follow the emergency guidelines and instructions provided by the company. They are aware of their actions and of the consequences of their behaviour.

The decisions in the cognitive component lead people to different behaviours. Figure 2 presents typical relations between the decision-making process on the cognitive component and the behaviours during an emergency with evacuation in large-scale event scenarios. In particular in cases where people should evacuate from the site of an incident and inconsistencies are found during the risk identification phase, people may assume a disengaging behaviour and might not 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 can do this by following an assumed leader, who may be, e.g., an experienced family member or an officer of an operational force.

In industrial area scenarios, if there are inconsistencies during the risk identification phase, people may also assume a disengaging behaviour and might not react to the threat until the inconsistencies are resolved. In the second phase, if people assess the threat as having low severity, they may assume the curiosity behaviour and approach the threat. If the assessment is false, they will put their own safety at risk. People who become uncertain tend to follow others in their competitive, curiosity or leader following behaviour. If people are certain about what to do, they will follow their own action plan or the process determined by the company. In case of deviation from the official action plan, individuals may just select a leader to follow, who will usually be the person responsible for safety in the company.

3.3. Affect Component

The affect component refers to the emotions triggered during an emergency situation. It refers to the feelings of an individual and how intense those feelings are. They are triggered by physiological and cognitive factors [11]. According to Plutchik [12], there exist eight types of human emotion, consisting of four opposite pairs, as shown in 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 every detail.

Emotions are one of the most obvious (and visual) aspects of human reactions. Humans are capable of perceiving the physiological response of other people's organism, such as heart rate or respiration and, in this way, of guessing their emotional state. This is the reason why human reaction in emergency cases is often described in terms of affect. This implies that feelings in a crowd play an important role. This is a stimulus coming from the social group in relation to the situation [13]. If people in the crowd feel anxiety, this stimulus may influence others who have perceived it.

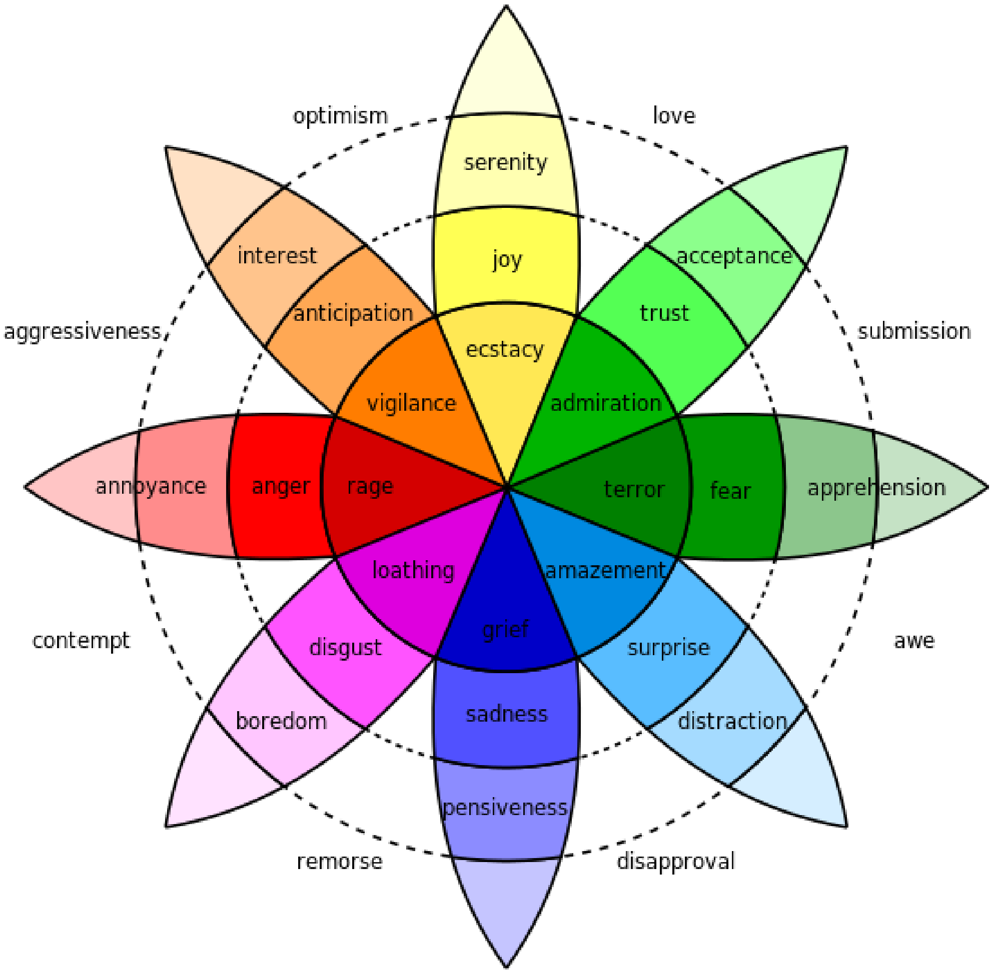

Figure 4: Emotional states based on Plutchik's emotional wheel [12]

3.4. Reaction Changes, Stress Factor and Interaction Capabilities

Even when an individual develops a certain reaction in relation to an emergency situation, this reaction is not fixed and can be changed. The cognitive decision-making process runs continuously. It checks for new environmental stimuli in order to assess the severity of the situation and to adapt the action plan accordingly. Important factors that influence the assessment of the severity of an emergency situation are:

- **Distance** from the threat
- **Time span** from the threat

When people increase their distance from the threat, their behaviour will adapt – the assessed severity level of the threat will decrease. Likewise, when time passes, the situation might be assessed as less severe, since the emergency situation might already be under control. For instance, during a fire alarm in a production plant of an industrial area, people will decide to leave the plant. Driven by fear, they might just follow the leader, obeying the instructions of the shift supervisor. As soon as they are outside of the plant, based on new environmental conditions, they suddenly start behaving in a process-oriented manner. They will most probably feel calmer and 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] includes the most current assumptions about the concept. McGrath [14] describes stress as the interaction between three elements:

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

This means that as long as the individuals have the impression that they can react to the stressor based on the current resources and have the internal motivation for doing so, the level of stress is low. If resources and motivation cannot fulfill the demand, the level of stress is high. In this context, distance and time affect the three elements that describe stress. The closer to the threat an individual is, the higher his/her level of stress will be. In the same way, right after the occurrence of the incident that represents a threat, the level of stress is high, which is especially caused by uncertainty and the individual's state of anxiety. Figure 5 also illustrates the influence of distance and time span on the level of stress.

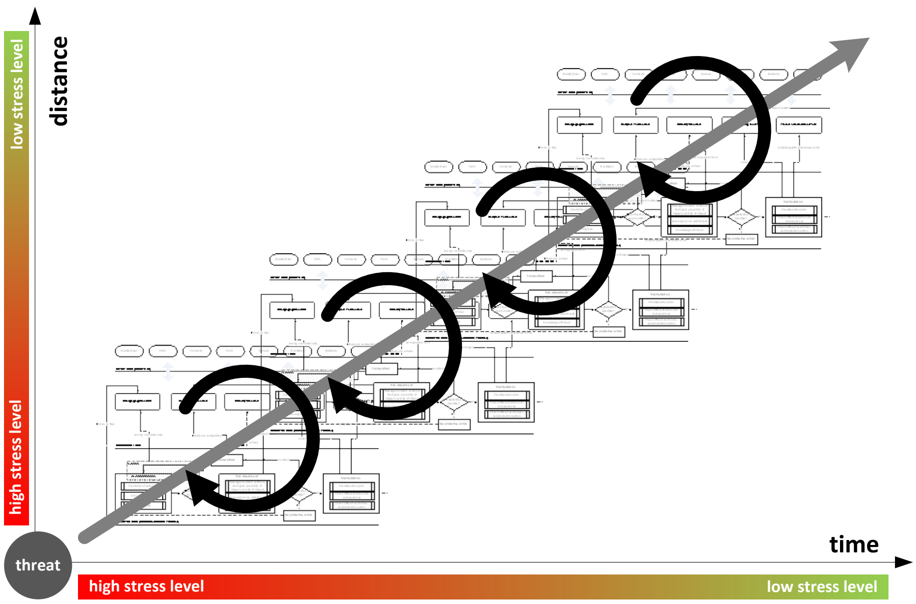

Figure 5: Human reaction and stress factors

Additionally, Staal [10] discusses the influence of stress in cognition and human performance. He figured out that stress, especially stress related to anxiety states, impairs the working memory, where the decision-making process (see section 3.1) takes place. He affirms that under stress the resources available for the working memory are reduced, consequently the scope of *attended stimuli* is also reduced. Particularly affected are points in the process responsible for the encoding, rehearsal, and retrieval of information. This means that individuals have their capability of understanding and recognising information reduced.

When the stressor is of an emotional nature, e.g. related to anxiety states, peripheral events are remembered less often [10] because individuals tend to concentrate the available resources on solving the primary task. The reduced availability of resources affects the processing of the perceived stimuli. The result is that changes in the environment that are not directly related to the primary task are not processed.

Moreover, the interaction with an information system also requires resources of the working memory. Figure 6 presents a model human processor that shows that the processing of information perceived during the interaction with an information system also occurs in the working memory [15]. "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].

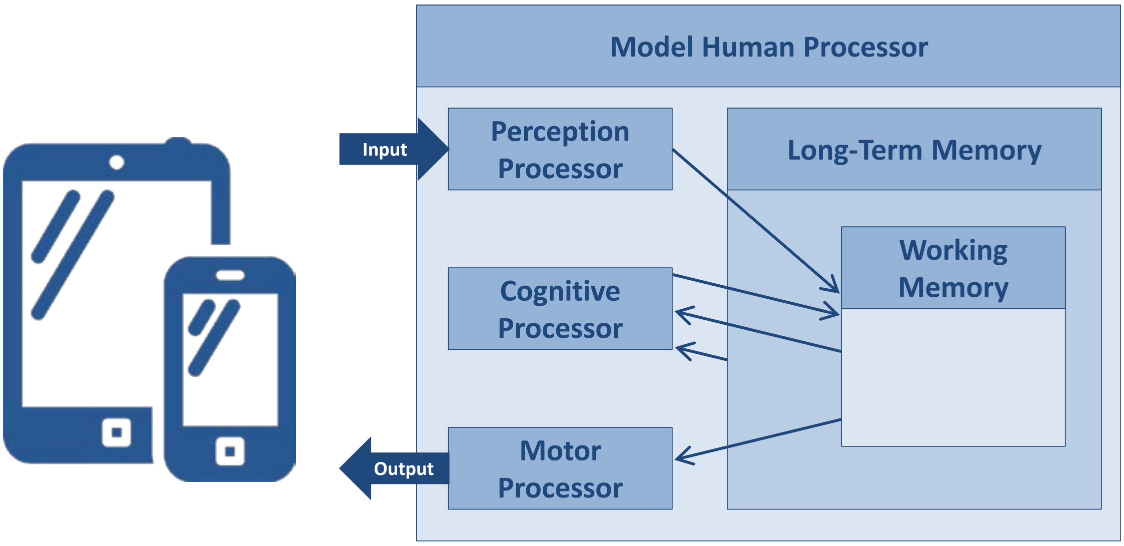

Figure 6: Model human processor adapted from Card et al. [15]

This means that, depending on the stress level, people might be impaired in terms of interacting with information 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 is possible after individuals achieve levels of stress in which enough resources are available for the processing of information.

On the other side, several authors demonstrate 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 affected by stress. In this case, the activation of such memories would lead the user to a kind of automaticity and fewer mental resources would be required for the execution of the task [10].

4. Strategy for Gathering Information

In this chapter, the overall strategy for coping with cognitive consumption in emergency situations is described. Figure 7 depicts the general idea for approaching the challenge of limited cognitive availability. It can be assumed that cognitive consumption of an emergency situation is based on two factors:

- **Time span** – As already discussed above, 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 less time that has passed since the occurrence of the incident, the less information about the emergency situation is available and fewer actions have been taken to control the situation. This causes stress because it is either obvious for the people at the place of the incident that their life is at stake or they have not had enough time and information to assess the danger. The more time that has passed, the more time and information a person has had to assess the danger and come up with an action plan for dealing with the situation.
- **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.

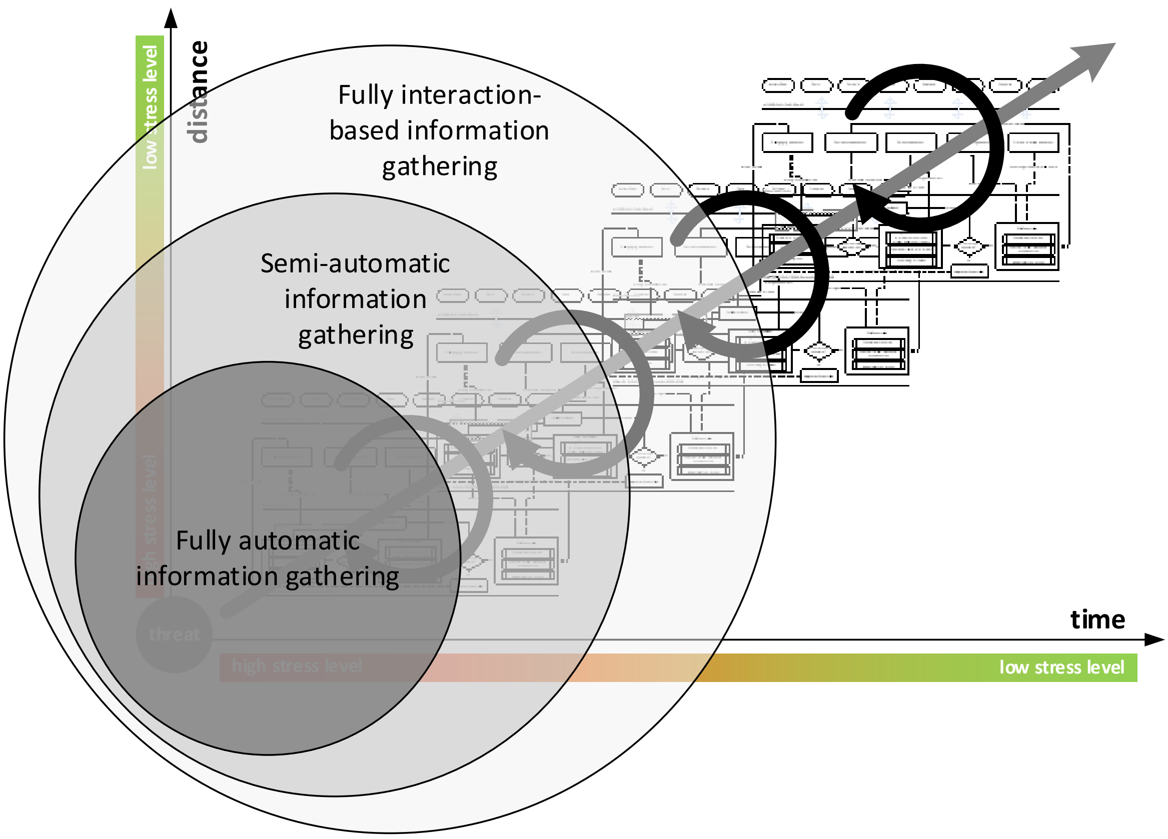

Figure 7: Information gathering modes depending on distance and time span

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 three different modes of information gathering: fully automatic information gathering, semi-automatic information gathering, and information gathering based on full interaction. According to our theory, the closer the distance to ground zero and the less time that has passed since the incident, the more information has to be gathered automatically. The current characterisation of the three modes is as follows:

- **Fully automatic information gathering** – All information that is relevant for the emergency and crisis management system has to be gathered automatically. Since the emergency situation completely consumes people's cognitive workload, they are unable to respond to any request or complete any task on the user interface. Therefore, mobile applications have to be able to automatically gather all information that is relevant for describing the situation. Actually, there is a lot of implicit information that can be considered while automatically gathering data: the user is very likely located within the direct perimeter of the incident, and the incident has not occurred long ago. In this mode, the emergency and crisis management system can only gather data provided by the physical sensors of the mobile phones, but these data have high relevance.
- **Semi-automatic information gathering** – People are still not able to respond to complicated interaction demands, but they can at least provide a little information about the emergency situation. The interaction needs to be as basic as possible, since people are expected to be still around the place of the incident and cannot execute a large set of actions with their mobile devices. Therefore, it is advisable to pose precise questions (e.g., based on the sensor data gathered automatically from the mobile phone) and ask them to execute easy and fast actions (such as making multiple-choice selections).
- **Fully interaction-based information gathering** – When people who eye-witnessed an emergency situation are no longer at risk of being injured, they may become observers and can contribute information about the situation more actively. By then, their cognitive workload is no longer consumed so much by the situation, and they can properly interact with their mobile devices. Due to the distance and time span, all information that can be gathered from the physical sensors of the mobile device might not be as important as in the other modes.

Figure 8 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. In this phase, fully automatic information gathering is recommended. As soon as the stress level decreases, cognitive capability is released, making semi-automatic information gathering possible. Once the level of stress is low, the cognitive capabilities available for interaction with a software system return to normal and people are able to fully interact with their devices.

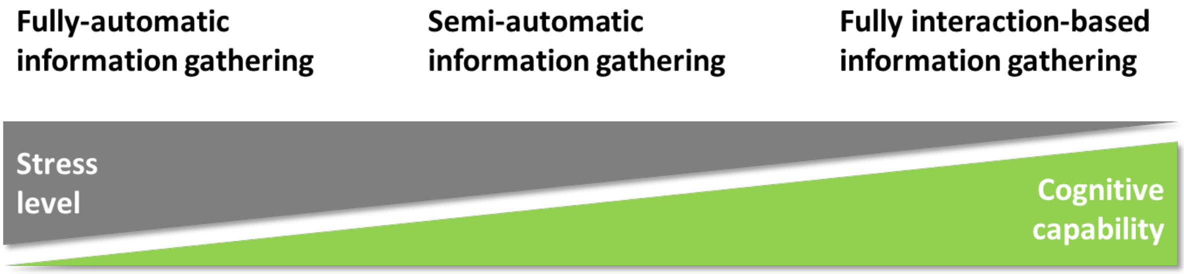

Figure 8: Relationship between stress, cognitive capabilities, and information gathering modes

5. User Interface Guidelines

In general, the usage of mobile computing (and its design) in the context of emergency situations is “widely under researched” [17]. In the following sections, we present UI guidelines for mobile application design that should be adhered to in order to enable non-negative user experience during an emergency situation. These guidelines have been derived from the literature review and represent a preliminary set of UI guidelines. They will be enriched throughout the project, taking into consideration the evolution of the requirements specification of the RESCUER platform (deliverables D1.1.x).

The proposed UI guidelines are: simplicity, accuracy, instant usage, error tolerance, and flexibility. They are based on the assumption that the available cognitive workload of the users will be limited.

5.1. Simplicity

UI design is a crucial part when developing mobile applications for emergency situations. Designers have to pay “serious attention to the display of information” [18] because inappropriate UIs waste the users’ cognitive workload availability, regardless of whether the users are eyewitnesses or formal responders. The result is that the users are either distracted while using such an improper mobile application or that they just do not use it. Thus, it is important for the UI to be as simple and minimalistic as possible, and intuitive to use [19]. Examples are:

- No unnecessary information: only the information that is necessary to cope with the situation should be displayed.
- Text messages must be short and the language used must be precise in order to avoid misunderstandings.

5.2. Accuracy

Since human lives are at stake and any wrong decision may lead to injuries or death, 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 improves accuracy in a software system is validation of the data before they are processed. This allows avoiding at least some deviations [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 accurate as demanded by the granularity of the information. The entire system state needs to represent the current state of the emergency situation.

5.3. Instant Usage

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

- No training material should be necessary for interacting with the mobile application for emergency situations. 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 in order 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 become active by regular activation or a push notification can be sent (proactively and based on the location) to the user after the detection of an emergency situation (if such notification has been previously authorised), and the user then activates the application.

5.4. Error Tolerance

It is important to prevent the user from entering wrong input or input that may lead to drastic consequences [19,21].

For example, if the user is prompted to provide a certain numeric input, only entering input within the valid and expected range should be possible. Other values that may corrupt the system state have to be avoided.

Once the user navigates the system to an undesirable system state, this fact 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 totally prevented in emergency situations. 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.

5.5. Flexibility

Since people in emergency situations are facing a situation that already consumes large parts of their cognitive capabilities, they do not want to spend any effort on adhering to 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 any information input people in an emergency situation want to provide. As a consequence, the interaction design has to contain as few constraints as possible regarding the interaction concept. Examples of measures for achieving 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).

6. Conclusion

In this deliverable, we propose a human reaction model concerning emergency situations that was created based on a literature review and an expert workshop that took place on 3 December 2013 in Linz, Austria. 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 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. Based on this understanding, we proposed a strategy composed of three modes of information gathering that take into consideration people's available cognitive workload in emergency situations. The three modes are: fully automatic information gathering, semi-automatic information gathering, and fully interaction-based information gathering. The level of stress is one of the relevant factors influencing the available cognitive workload, which is in turn influenced by the distance from the site of an incident and the time span since its occurrence.

The next step was to define basic guidelines for enhancing the usability and user experience of mobile applications in order to support emergency and crisis management from the viewpoint of the eyewitnesses and formal responders at the site of an incident. 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, and crowd steering by the command centre, will be the subject of the next two versions of this document, to be delivered during the second and third iteration of the project, respectively.

RESCUER

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Glossary

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 Critical situations caused by incidents, natural or man-made, that require measures to be taken immediately to reduce their adverse consequences to life and property.
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 that caused the emergency situation. First responders are also eyewitnesses.
First Responders People at the place of the incident that act to protect themselves and other individuals as well as to minimise the consequences of the emergency situation.
Formal Responder Members of the operational forces 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 smartphones that might be used and how people interact with smartphones under stress.

Abbreviations

RESCUER Reliable and Smart Crowdsourcing Solution for Emergency and Crisis Management

UI User Interface

UX User Experience