Designing for acute stress in emergency situations

Guidelines for user interfaces of avalanche transceivers

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ABSTRACT

If buried in an avalanche, the greatest chance of survival is through companion rescue with the use of avalanche transceivers. The use of these receivers is however challenging since human performance in an avalanche rescue scenario is very likely to be affected by stress. This article looks at the effects of stress on human performance in an avalanche rescue scenario and discusses how the interface of an avalanche transceiver can be designed to account for such stress effects. The article provides guidelines for the interface of avalanche transceivers covering the following areas: physical ergonomic features, redundancy, information acquisition, graphical user interface and human error.

KEYWORDS: Stress, Acute Stress, Interface, Avalanche Transceivers, Design, Guidelines

1. INTRODUCTION

The human performance in any given situation is always going to be dependent on a variety of factors. Sleep, anxiety, physical strength, heat and noise are just some examples. Some factors will have a higher impact and interferer more with ones ability to cope than others will. This article will look at a factor, which has the potential to change the outcome of a situation completely, and in a worse case scenario degrade human performance to a minimum. This factor is stress.

Today various electronic devices are used as tools to aid people in emergencies when they might be under the influence of stress. Two examples of such devices are defibrillators for use in first aid situations and the use of fire alarm control panels during fires. Because of the stress aspect, the interfaces of such devices often follow different norms and rules than interfaces of other devices, used under circumstances that are more normal. Hancock and Szalma state that when designing for high-stress situations designers have to understand that they are dealing with limited capabilities [1].

Another emergency situation where the use of electronic tools is becoming increasingly more common today is during avalanche rescue operations, with the use of avalanche rescue transceivers [2].

If being buried by an avalanche time is the most crucial factor. Research based on data from 194 avalanche accidents in Austria from 1994 to 2003, involving 278 fully buried victims shows that if extracted from the snow before 15 minutes has passed, survival probability can be as high as 90% [2]. After this time, survival probability drops significantly.

Approximately 60% of all victims completely buried by avalanches die from asphyxia between 15 and 35 min after being caught by the avalanche [3]. Between 90 and 120 minutes the survival probability drops another 20% [3]. As a result of this most organized rescue operations fail to recover avalanche victims alive [4]. This means that companion rescue with avalanche transceivers is your greatest chance of survival, should you be unlucky enough to get buried in an avalanche [4].

Ever since avalanche transceivers were introduced by Dr. John Lawton in 1968 they have gone from being tools used only by professionals (technicians, mountain guides, ski patrols, rescue personnel) to becoming commonplace among off-piste- (near organized ski slopes) and backcountry- skiers and snowboarders [2, 5].

Some research has been published on avalanche transceivers, but this has mostly been focused on technical aspects of the transceivers e.g. range, signal frequency or optimization of search strategies. It is in the author's opinion that research on the user interface of avalanche transceivers is yet to be examined. In a report from 1997 by members of the Swiss Federal Institute of Snow and Avalanche Research and the International Commission for Alpine Rescue, it was concluded that existing avalanche transceivers were too complicated for the majority of users to operate effectively [5]. Even though much have happened since then within the fields of research and product development, the term user interface is rarely explored more than to the extent that an avalanche transceiver should be "intuitive" or "user friendly". This article aims to provide guidelines for how to design interfaces for avalanche transceivers.

In order to do so, a literature review has been conducted, including literature from avalanche research, cognitive psychology, and human factors and ergonomics. The first part of this article will explore the concept of stress, before looking at some factors known to cause stress, so called stressors. After choosing a definition of

stress for further use, the article will look at the effects on stress on several aspects of human performance in relation to avalanche scenarios. Next, the article will briefly review the avalanche transceiver as a product (for example basic functions and how they are used). It will then provide guidelines for how to design the user interface of an avalanche transceiver. Finally, the article will discuss the matter of individual differences when it comes to interface design.

Although the best practise for how to reduce the number of people dying in avalanche related accidents, might be to increase awareness on how to avoid them, rather than how to survive them, this will not be discussed in this paper.

It should also be mentioned that there are other avalanche safety tools that might be good alternatives to use in addition to transceivers, like avalanche airbags or avalanche breathing systems.

2. STRESS

2.1 Understanding the term

Stress has been studied from various perspectives in both technical, social, biological, physiological and psychological sciences [6]. Some researchers claim that the versatility of the term is its undoing as it has been used to describe everything from internal forces in suspension bridges to human behaviour [7]. It would seem that researchers are struggling to come up with one common definition of exactly what stress is and what causes it [7]. Experiments that aim to provide some empirical data on the term have often been criticised for their lack of validity. However in order to conduct experiments with a high level of validity ethical considerations has to be made [6].

One of the theories which often has been used to explain the effects of stress on performance is called Arousal Theory [6, 7]. In this theory the term arousal is defined as the level of any kind of mental activity whether it be anger, alertness,

anxiety, drowsiness or something else [6]. Later the arousal term has been used synonymously with stress [7]. This theory is interesting because it specifies that arousal does not always have to be negative. In fact some arousal can actually enhance human performance up to a specific point, called the optimal level of arousal [6]. Some stress can in other words make you better suited to handle an emergency. The Arousal Theory has often been interpreted within Yerkes Dodson law [6, 8]. This law theorize an inverted U shaped correlation function between arousal and performance.

As shown in figure 1 the human performance increases up to a point before it decreases again [6]. Another interesting aspect with the Yerkes Dodson law is that the optimum level of arousal tend to decrease with the complexity of the task [6].
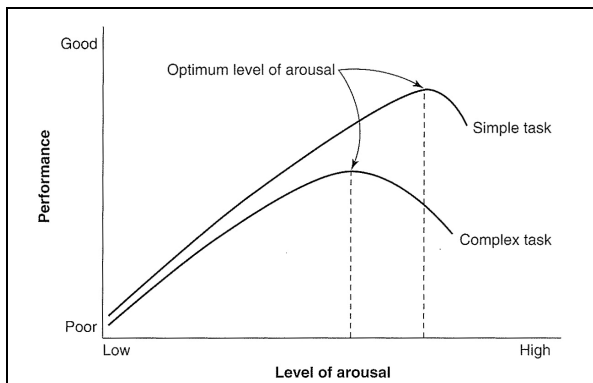

Figure 1: The relation between performance and level of arousal [6]

2.2 What causes stress?

Factors known to cause stress are often referred to as stressors. These can be classified as having an external or internal influence on human performance [6]. External stressors encompass environmental factors like noise, heat, vibration, dim lightning, or acceleration, but also more abstract factors like time pressure or penalties for poor performance. Environmental stressors might have an influence on perception and the quality of information received. They might also

affect precision or motor performance [6]. Time pressure will affect the time that information can be processed and thereby naturally degrade performance [6]. In an avalanche rescue scenario time pressure is likely to be the most prominent stressor because the survival probability of a buried victim is extremely time dependent [4].

Internal stressors include physiological factors like anxiety, frustration or anger [6]. These might affect human performance in a similar way as the external ones but they are more difficult to measure and not as well understood as external factors.

External and internal stressors are often closely linked. This makes it difficult to determine whether a stress reaction was the consequence of an external or internal stressor, or both. Traditionally though stress experiments have usually been conducted using external stressors as stimuli [6]. Researchers have chosen a variable (e.g. pain or noise) applied it to a test subject, and then concluded that the outcome was likely the result of stress manipulation [6]. These types of experiments have been criticised by many who are claiming that people are not machines that simply react to different kinds of environmental stimuli but emotional characters with individual differences [6].

2.3 Towards a definition

Stress is clearly a comprehensive term. For reasons of simplicity this article will use a definition of stress proposed by McGrath, who defines stress as the interaction between three elements [7]:

  I.   Perceived demand
 II.   Perceived ability to cope
III.   The perception of the importance of being able to cope with the demand

To clarify this definition, imagine a scenario in which you are alone in the mountains and your best friend has just been buried by a big avalanche. His only chance of survival is you

rescuing him by locating him with your avalanche transceiver and digging him out. In this situation both the perceived demand (I) and the perception of importance to cope (III) will undoubtedly be very high. However if you happen to be an experienced mountain guide who has participated in numerous avalanche rescue operations, your perceived ability to cope (II) might also be high resulting in a relatively low level of stress.

This example also illustrates how both external and internal factors affect stress. In this scenario, the perceived demand of the situation will be dependent on external stressors like wind, cold, visibility etc. While the perceived ability to cope and the importance of being able to cope will be more dependent on internal stressors like psychological factors.

3. EFFECTS OF STRESS ON PERFORMANCE

This section will explore the effects of stressors, on human performance in emergencies. Some of these are reactions that one might expect to occur in any kind of emergencies, while some are more specifically related to avalanche scenarios.

3.1 Motor-perceptual performance

Wind, cold, and decreased visibility are external stressors likely to influence the motor-perceptual performance of anyone taking part in an avalanche rescue scenario. Cold temperatures in a combination with wind affects all elements of muscular performance, such as endurance, strength, speed and coordination [9]. Decreased visibility due to fog or snow might also degrade hand eye coordination. In addition to this protective clothing will reduce mobility and sensory experience, making tasks that require fine precision harder to perform [9]. The energy cost of performing a task will also increase with the use of protective clothing [9].

Although extreme environmental conditions are known to degrade human performance, research

shows that motor-perceptual skills tend to be more resilient to stress effects than other cognitive processes like attention or working memory [7].

3.2 Attention:

In everyday life our attention is overloaded with information, although our ability to process all of it is limited [10]. In situations regarded as stressful, the system becomes overloaded affecting our attention [11].

Selective attention is the process that allows us to focus on those stimuli that we find relevant [10]. It can be described as the filter that determines what information is processed and what is discarded [10]. In highly stressful situations attention is known to narrow, reducing focus on peripheral tasks and information, to the stimuli which is perceived to be of greatest importance to the individual [7]. The exclusion of information irrelevant to the task at hand is called cue utilization [10].

Narrowing of attention can however have both positive and negative consequences on performance, depending on the task at hand and the scenario [7, 10].

If a task requires the exclusive attention of an individual, attentional narrowing can be a good thing, allowing the subject to focus more on the current task (e.g. a climber in a wall). However if peripheral information and cues are related to the task at hand, this will affect the performance of an individual, who might discard useful information (e.g. a meltdown in a nuclear power plant).

Some researches claim that even the visual field can be a subject to narrowing under heavy workloads, a phenomenon known as visual tunnelling [12]. Research by Rantanen and Goldeberg showed that both size and shape was affected when applying heavy mental workloads to test subjects [12]. This could potentially have an effect in an avalanche rescue search where

the goal is to locate someone who might be fully or just partially buried by snow.

In addition to this researchers have also explored the effects of noise on attention [7]. The results here were that noise reduces the ability to detect signals, increases inefficient performance, resulting in more human errors, and an increase in selective attention [7]. Research also shows that intermittent noise tends to disrupt performance more than continuous noise [7].

In an avalanche rescue scenario noise from the wind is likely to be present, but since this is closer to continuous- than disruptive noise the effect on performance will probably be limited. A high level of continuous noise might however impair communication between people taking part in a rescue [9].

Another phenomenon which researchers claim to be the effect of attentional narrowing is the experience of time distortions [13]. In potentially life-threatening situations people have reported distortions of time, usually in the sense that the timespan of an event seems longer than what was actually the case [13]. A theory proposed by Hancock and Waver postulates that since an individual's attention in a stress situation, might be narrowed down to task related activities, time based cues are discarded resulting in time distortion effects [13]. This stress reaction is interesting in avalanche rescue scenarios because the survival probability of a buried avalanche victim is very time sensitive. If an individual taking part in the search of a buried victim feels that more time has passed than what is actually the case, this can affect the perceived demand of the situation resulting in an enhanced stress reaction.

3.3 Memory

When it comes to the effect of stress on memory, working memory is the function known to suffer the most [7]. Working memory refers to the capacity to store and employ information over short periods of time [10]. It is the process which

allows us to keep track of multiple sources of information that can be used to generate responses on what to do [10]. In general research shows that impairments in working memory are most likely when the workload is high [10]. The effect of stress on working memory is important because it provides constraints for how much information should be provided to a user through the interface of a system.

In addition to working memory stress is also known to impair retrieval of memories [10]. Experiments have shown that physiological stressors leads to people having difficulties remembering previously learned information [10]. In an avalanche rescue, this could mean that even if though someone have practised using their avalanche transceiver multiple times, an enhanced stress reaction might cause them to forget this practise, resulting in poor human performance.

3.4 Situation awareness

According to Endlsey situation awareness (SA) refers to being aware of what is happening around you and understanding what this information means to you in the near future [14]. People can achieve SA on three different levels [14]. At the first level the user is gathering information about the surroundings through attention [14]. At the next level this information is transformed into a comprehension of the current situation [14]. Finally on the third level the user is able to project the future status of surrounding elements based on his understanding of the situation [14]. This status can then be used to make a decision on what to do next.

How much information should be provided by a system in a stress situation, will be a trade off between providing just enough information to facilitate a high level of situation awareness, and limiting the amount of information to prevent information overload. In an avalanche rescue, this might create some interesting dilemmas.

Should the interface of an avalanche transceiver provide the time passed since the transceiver was switched to search mode indicating how long the victim or victims have been buried? Should the interface indicate the heart rate of buried victims so a searcher can choose to search for the ones that are more likely to survive? On one hand, this information would enhance situation awareness in an avalanche rescue operation by offering a more complete image of the situation, but on the other hand it might facilitate an enhanced stress reaction by making the process of judgement and decision making more psychological demanding.

3.5 Judgement and decision-making

Judgement and decision making are often considered the end state of the mental processes mentioned before: Information is collected from the surroundings through attention and processed in the working memory generating a level of situation awareness, before judgement and decision making processes generate a response [7].

Research shows that exposure to stressors can lead to something called hyper vigilant decision making [7, 10]. This process can be characterized by a non-systematic and rapid search for information, a consideration of only a few alternatives and no re-evaluation of previously made decisions. The use of hyper vigilant decision-making in laboratory experiments has proven to affect human performance in a negative way because relevant data that could enhance situation awareness is neglected [10]. Decision making does however tend to be more rigid with fewer alternatives [6, 7].

Furthermore there is evidence that people tend to use the same response strategies that they have used before, regardless of whether this had a successful outcome or not [7]. Because of this people will often discard new information that doesn't comply with their strategy [1]. This can make them proceed with a strategy of action, even after it has ceased to be helpful [7].

In an avalanche rescue scenario with multiple buried victims the decision making process can be especially demanding. Because the digging process might be very time consuming only one in ten avalanche victims with a burial depth of more than 1,5 meter is likely to survive [2]. This might force a searcher to choose between digging up one victim and locating another. If a searcher in addition to this has cues on who is buried where based on e.g. where they were last seen, how will he prioritize what to do?

3.6 Human error

Human error is inevitable in all phases of human performance [6]. It has been estimated that between 60 and 90 per cent of major accidents in complex systems such as nuclear power, process control and aviation are caused by human errors [6]. However whether human error is the result of stress or the other way around, can often be very difficult to determine [6]. Many of the errors that people commit are however the result of bad design, and can be reduced by products and interfaces that are more prone to error [6]. An example of such a design feature is the prompt message that appears when you close a program on your computer to ensure that closing the program was done with intention.

In an avalanche scenario incorrect use of rescue equipment, whether it is probing-, shovelling- or transceiver search technique can have great consequences. An example that illustrates this is an avalanche accident that took place in Eikedalen in Norway in 2011. Here the localization of the buried victims was delayed, due to volunteer rescue personnel searching in the avalanche area with their transceivers in the wrong mode, thereby interfering with the signal from the buried victims' transceivers and delaying the rescue operation [15].

4. ABOUT AVALANCHE TRANCIEVERS

Avalanche transceivers are the most widely used emergency equipment for use in off-piste and backcountry activities today [2]. In order to provide some guidelines for how to design interfaces for these devices some info should first be provided on how they work, without going deeply into technical details.

An avalanche rescue transceiver has two modes; send and search. When in the send mode the transceiver transmits an electronic signal with a standard frequency of 457 kHz [16]. This signal can then be received by a transceiver in search mode. The searching transceiver can determine the range between the two transceivers based on the strength of the signal. The maximum range of most transceivers varies between 40 and 80 meters depending on the brand [17].

Todays transceivers uses digital signal processing, meaning that they capture the pulse from another transceiver, transform it into digital signal information, interpret the signal with a microprocessor, and then present the data to the user [5]. This is usually done visually with the use of displays that show distance and direction to the buried victim [5]. The visual display is often supplemented by an audible signal, which can vary in frequency, intensity and volume depending the on distance from the victim.

The functional features of avalanche transceivers are usually limited to a minimum. On some transceivers however the user is able to recall more advanced functionality by carrying out specified commands like pushing two buttons simultaneously for a given number of seconds.

One feature however that has become very common in modern transceivers, in addition to sending and searching, is the multiple burials function. This enables searchers to mark and filter out the signal from a located victim, before moving on to search for another one.

Although transceivers have become increasingly common in backcountry recreational activities today many users tend to have little experience with using them [5]. Many are often first time owners, and once they have made their purchase they seldom practise searching [5]. This calls for transceivers which have a very short learning curve and that can be operated even under the influence of stress.

5. DESIGN GUIDELINES

5.1 Physical ergonomic features

Both the device and the controls should fit the body part that is to operate it [18]. Because having one hand free while searching would be desirable the transceiver should be able to be operated, with just one hand. Since users probably will be wearing gloves, fine precision will be impaired [9]. The interface should therefore provide adequate space between controls, so they aren't activated accidentally [18]. The design should also create a sense of tool orientation from the field of the grip so the user is pointing the transceiver in the right direction when searching [18]. In addition to this left hand users should also be considered when it comes to the position of buttons on the device.

5.2 Redundancy

Redundancy refers to repetition of content in a different format [19]. Redundancy can reduce the demand on working memory by increasing the users awareness of the effects of his or her interactions with the system [19]. This can be especially effective under stress when attention is likely to be impaired [11].

An avalanche transceiver should provide redundancy in form of both visually, auditory, and tactile feedback. Buttons should be terminated with a mechanical stop, while auditory feedback should be given to indicate a change in the system invoked by user interaction [18]. Furthermore, auditory feedback should be provided while the device is in search mode,

since the user is likely to be looking around while searching, and not directly at the display. This auditory cue should increase in intensity as well as frequency and volume when getting closer to the buried victim. The volume of auditory cues should be at least 10 dB louder than the background noise and differ in frequency [20]. In an avalanche rescue operation, the background noise would primarily be caused by the wind.

Protective clothing (e.g. gloves helmets) along with outer stressors like noise from the wind and, or low visibility will however impair sensory experience and should be accounted for when determining the magnitude of the sensory feedback.

5.3 Information acquisition

According to Rasmussen the way that people process information can be categorized into three different levels based on the amount of conscious control exercised in a given situation [21]. The skill based level refers to a more or less automatic processing of signals from the environment resulting in actions that require very little conscious control [18, 22]. During rule-based information processing an individual uses established rules as the basis to carry out a specific action [18]. At the knowledge based level the individual carries out the action in an almost completely conscious manner [22].

According to Braseth & Øritsland the amount of information that an individual is able to acquire in a given scenario tends to decrease with the demand of the situation as illustrated qualitatively in figure 2 [23]. A stress reaction might in other words reduce the information that can be acquired through an interface.
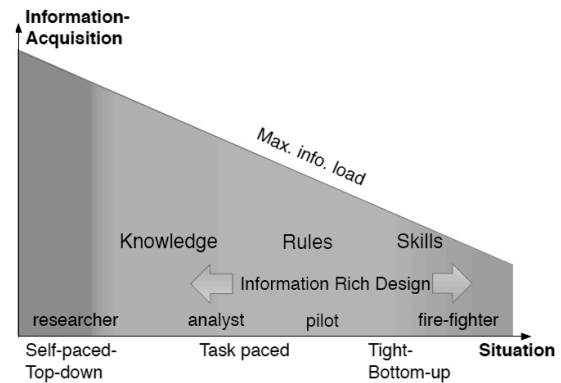

Figure 2: Information acquisition in relation to situation demand[23].

Under extreme conditions the transceiver interface should therefore try to avoid providing information that requires much mental processing on the knowledge based level, in order to come up with a response [1]. This is especially important since working memory is likely to be impaired [7]. Providing information to be processed on the skill based level should also be avoided since this would require that the transceiver has been used frequently by the user to a point where interaction is almost automated [22]. Unfortunately this not the case for most transceiver owners [5].

Instead the transceiver interface should aim to provide simple instructions on the rule-based level. The user should get instructions on what actions to take during the different steps of an avalanche rescue operation [1, 6]. This would for instance mean that when a searcher is within immediate proximity of a buried victim the interface should tell the searcher to "Start probing", rather than "You are close to the buried victim". Information should also be provided only when its needed by the user [18]. This would for instance mean that for a transceiver in search mode, the multiple burials function should only be visible if there is more than one burial.

The amount of information provided in an interface for use under stress should also be minimized. Since attention is impaired all

unnecessary information should be avoided [1]. An example of this found in most avalanche transceivers today is that distance is displayed only in figures, without any unit of measurement, as opposed to what one might expect from other devices used for navigation like GPSs.

5.4 Graphical user interface

The graphical user interface should follow basic principles of layout. The most important and frequently used elements should be centred in the display [18]. For the transceiver this would include the directional arrow and the distance to the buried victim, as well as important instructions like when to start probing. Elements should then be arranged after how frequently they are used [18]. If there are multiple burials, this should be indicated in the display. However since this information is not directly related to the current task, which is locating the closest victim, it should be given less priority. Elements should also be grouped after the function they represent. This means that elements indicating multiple burials should be grouped together.

The size of the display or display elements should also be given attention. At a viewing distance less than 0,5 meters alphanumeric character should not have a height less than 2,3 mm [20].

To ensure a good figure-ground differentiation graphical elements should have a strong contour [20]. Because the user is going to be moving around while using the device, the display should also have a high level of glance legibility, referring to the amount of information that the user is able to percept with just a quick glance [18].

Since information acquisition and attention is impaired under stress the designer should be careful with using graphical elements that are too abstract so the user has to process information on the knowledge based level [22]. To facilitate behaviour on the rule based level the designer can use icons or pictograms that are either known to the user from common interfaces, or ones that that provide enough information to be understood regardless of whether the user has seen them before.

A reflection based on color-coding should also be given. Color coding of display elements can draw attention to specific data, aid a faster uptake of information and speed reaction [20]. Having multiple colored elements can however impair the contrast ratio if the background color remains uniform throughout the display. In an avalanche scenario reflections from the sun and snow are likely to cause a screen glare, which will reduce the contrast ratio further and impair legibility. One should therefore be careful with using multiple colors on the display elements of the transceiver. Color-coding should however be considered on physical points of interaction, like buttons or switches.

5.5 Human error

Controls should be labelled, and arranged in a way that prevents accidental activation [18]. Redundancy should be used to give feedback on any input. One control, which should be given extra attention, is the switch that toggles the two modes search and send. This switch should provide multiple sensory modalities when toggled, and perhaps have a locking function. The display on the transceiver should provide instructions on correct searching technique at the different stages of the search.

6. DISCUSSION

The design guidelines provided in this article do not account for how individual differences in various human abilities affect performance under stress. Stress levels vary with people and situations and some might have developed coping strategies for supressing the effects that they otherwise might suffer from [11].

With individual differences comes the aspect of the skilled versus unskilled user. Although many of the manufacturers emphasize that practising with your transceiver is utterly important, this is

forgotten by many [5]. Within the professional user group, this is however, a different manner as these users often have conducted an extensive amount of avalanche rescue training. In a research conducted in the United States well trained professionals were found to be 77% faster in their search efforts with a transceiver, than recreationalists, and their success rates in finding victims alive were markedly higher (60% vs. 32%.) [24].

With this scenario in mind, having two different transceivers with different interfaces and functionality could be an option - one for recreationalists and one for guides and other professionals. This is approach to product development can be seen among first-aid equipment manufacturers who often create different defibrillators for non-professionals and ambulance staff [25].

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