A notification system for a landmine detector using distributed cognition

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ABSTRACT

This paper presents a design for a visual display to be added to mine detection equipment. It is an application of the tenets of calm computing to a safety-critical system by putting cognition outside the mind, aligning inputs within the centre of attention and along the periphery, and juxtaposing stimuli in close proximity to the source of the information, all with the aim of increasing safety.
The first iteration occurred in the redesign of a landmine detector is described, starting from a literature review of the related practices, concept design, mock-up production and, finally, heuristic evaluation and the brainstorming undertaken with experts in the field.

Keywords

Notification Systems, Calm Technologies, Landmines Detection, Distributed Cognition, Critical Activity Monitor, Humanitarian demining.

INTRODUCTION

This work is based on a study of the practice of landmine detection with the use of electromagnetic signals based detection technology [1]. The correct procedures for the identification, investigation and declaration of a buried object with a metal detector have been embodied in the device with the aim of distributing cognitive processing between the operator, the tools and the perceived and acted world. The basic idea was to face the issue of the cognitive load of the operator providing the landmine detector with a notification system display [2], [3] that could allow a presentation of the data in visual form, thus being isomorphic with respect to the target - the buried landmine - and at the same time to the surrounding environment - the soil, the topographical and geographical setting.

The spatial proximity between the display and the most important contextual elements that the operator must consider were also design issues **[4].**

A prototype and a scenario in a video format were built and presented to three experts in the field of humanitarian demining. We requested them not only to evaluate the concepts but also to make proposals and offer design ideas in order to push the project forward.

THE PRACTICE OF LANDMINE DETECTION

A mine is a device designed to kill or injure anyone who comes into contact with it in general through direct pressure. There are many different types of mines, all essentially consisting of a container containing explosive and a fuse. The main characteristics of landmines are their simple, no-maintenance and economic technology, combined with their persistent threat throughout the years. There are smaller mines aimed at people (AP) or larger ones aimed at vehicles (AT). The production of metallic landmines has been progressively replaced by that of plastic landmines, which are harder to detect [7].
At present, the most widely-employed way of scanning a territory is by using metal detectors. Basically, these portable technologies are composed of a search head, a connecting rod, a handle and an audio signal transmission system.

We isolated the basic steps of the practice of landmine detection from the work of James Staszewski, which analysed the best practices of a number of expert users [1]. These steps are: (1) to sweep the surface suspected of hiding landmines (search); (2) on receiving a signal, to try to repeat it in order to obtain confirmation; (3) to investigate its shape by matching the auditory information with the images of known landmines (investigation); and (4) finally, to declare the suspected type of mine (decision).

The initial phase consists of searching for buried mines, while “sweeping” the ground surface and lightly moving the detector over an area of 1.5 metres (the “lane”) with a cross-lane trajectory; if there is no signal, the operator moves on 15 cm, repeating the procedure, and so on.

When a signal is perceived, the operator tries to reproduce it by moving the tool over the critical area; if the sound is repeated, the investigation phase begins. The operator must elicit the shape of the object on the basis of the sounds emitted by the detector.

The possible actions for investigating an auditory signal in order to elicit the corresponding shape (and classify it) depend on the halo produced by the buried object. The halo is precisely the visual pattern imagined by the operator on the basis of the sound emitted or not, as the landmine detector is moved over the critical area; the halo of a landmine is normally circular, and its dimensions can vary widely based on the amount of metal that composes the mine and its dimensions. Other innocuous objects that can produce a signal may have different, non-circular halos that are difficult to distinguish from a mine. These tend to cause false alarms, which slow down the demining process and tire the operators.

From the description of the landmines inspection practice, it is possible to focus on three coexisting elements producing cognitive load: the first is environmental information interpretation; the second is the rehearsal and situated application of the inspection procedures (with all the geographical, temporal, sensory and motor related components); and the third is the interpretation of the data coming from the device. As for metal detectors, the absence of isomorphism between the signal and what is signaled in the investigation phase can be considered as an added cause of cognitive load. Proof of this is found in the radiating movements that the operator executes over a halo in order to build up a mental image [1].

We considered these issues as design problems and imagined a display integrating auditory information and embodying the procedures of landmines inspection routines. The solutions proposed are: (1) creating isomorphism, homogeneity and consistency between the data from the different sources, allowing the operator to organise them. (2) juxtaposing the contextual information (geographical/physical/environmental); and (3) furnishing the user with information organised at the centre and at the periphery [5] in order to meet the cognitive principle of the dynamical partition between the foreground and background [6]. The results are a set of artefacts that allow the situated manipulation of visual data about the environment in a transparent way, and organize the user's attentive view [9].

A number of devices are provided for visualisation support, but they are mostly located separately from the body of the tool, thus violating the principle of juxtaposition and the spatial proximity of the data. Otherwise, when a display is mounted on the landmine detector (e.g. the ALIS detection system [8]), it is located too close to the visual field, compromising the perception of the context which is crucial for the operator to achieve sensory-motor coordination and the analysis of the environmental factors.

THE REDESIGN

The main modification of the detection device is a circular display located over its main body with the aim of supporting the activity of the operator through instructions for sweeping and the visualisation of the halo (*fig.1*).

Fig. 1 The circular display mounted over the main body of the landmine detector

The basic idea is a system that takes a trace of the halo while the user moves the device, in order graphically to build it in progression while the user moves the detector; in this way, the auditory information will be grabbed and registered by the system in visual form.

As for the initial phase of the search (*fig. 2*), the arrows projected onto the screen will suggest to the user in which direction he/she should go. In this way, the user will not have to memorise the areas of the ground already scanned and those still to explore, but can simply follow the instructions of the system, that automatically calculate and display the trajectories.

Fig. 2. The circular display prototype: the phase of sweeping the ground

As for the investigation phase, when the operator has to decide the nature of the buried object individually, the system supports the detection of the halo by visualising it on the screen. *Figures 3* and *4* show the phases of inspection of a metallic and a plastic landmine respectively.

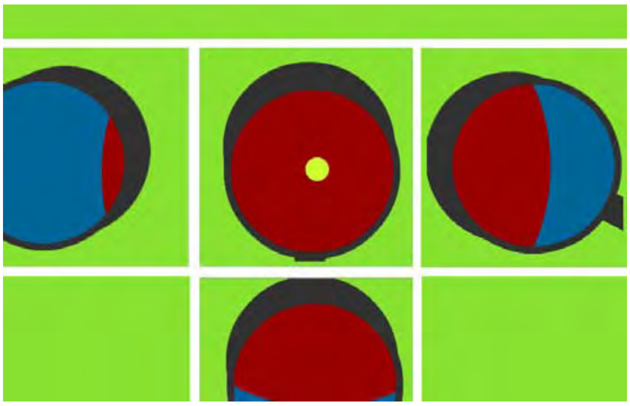

Fig. 3. The circular display prototype: radiating inspection of a metallic landmine

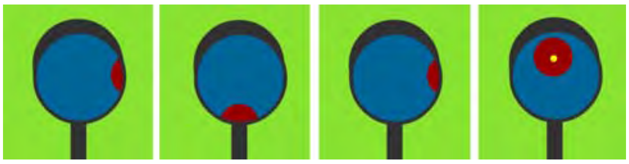

Fig. 4. The circular display prototype: radiating inspection of a plastic landmine

The benefits of the concept described lie in the tenets of distributed cognition. The working memory of the operator is partially relieved of switching between audio analysis, visual imagery, the recalling of the halos' classifications, sensory-motor and spatial cognition, the evaluation of the soil and the retention of the actions still to perform in order to complete the sub-procedures. Finally, the screen-based information would be sharable with the other components of the team, storable and thus available to others in different moments, to support the decision-making, training, and eventually, a second-time analysis.

After the concept design phase, video prototypes and a video scenario have been built in order to submit them to a group of experts in the field of humanitarian demining. They have been asked to perform a hybrid evaluation that would take into account not only the scenario produced, but also a review of an available solution for a dual sensor detector with a mounted display (ALIS) [8]. They have been solicited to express the opinions, ideas and visions raised by the exposition of these materials. A synthesis of their contributions is presented below:

In the past, when addressing the operator interface with the metal detector, we tended to ask the designers/manufacturers only to provide the operator with an audible output when detecting a target. The idea was to prevent the operator from losing focus on the ground, which could contain hazardous objects that could be triggered physically by contact with the search head. Newer detectors have, over the past couple of years, among other indicators, successfully integrated an LED bar, giving the operator a visual reading of the strength of the signal. Visual displays as an added source of information, decreasing the amount of false alarms, and in general determining a reduction in the human factors affecting the whole process of detection. On the other hand, they tend to overhang the field of vision and thereby increase the risk of making mistakes. The system proposed in the scenario represents an overcoming of the existent problems in that the display mounted over the body of the device allows the operator to maintain an acceptable field of vision, and requires only a short training session. The use of a display represents, in general, a shift in the paradigms of the detection procedures, and there is the possibility that the next generation of deminers, being used for computer games equipped with display glasses, could improve the system proposed in the scenario.

In sum, the experts' opinions were positive in that they acknowledged the improvement that visualisation can bring to the detection process, such as the importance of using a display mounted on a landmine detector in order to integrate the visual field unobtrusively. One of the experts envisioned a high tolerability of augmented environments in the near future, thanks to the diffusion of high technology computer games.

DISCUSSION

We tried to work with both the paradigms of distributed cognition [10] and disappearing technologies [9], [5], [11] in different phases of the project. They revealed common themes derived from cultural historical psychology, like the claim to amplify cognition by putting it outside the human brain [10],[11], or the intuition that an effective cognitive artefact tends to disappear from the attention of the user, as in the practice of writing.

The original contribution of the redesign described above lies in its attempt to locate the added source of information (the display) at the same level as the other elements of the visual field, with a spatial proximity to them, and with the same visual language. Moreover, the indexicality [2] of the information produced is pushed to a 1:1 scale, in order to furnish the user of a working landscape that tries to imitate a natural setting, and that allows the user to reason through manipulating information in a context-situated fashion.

The aim of employing a calm technology to the distributed cognition analysis of the operator's cognitive load is intended to allocate information in a dynamical and fluid partition between the periphery and the centre of attention. This is an organisational principle of perceptual stimuli (already recognised by Gestalt psychology [6]) that follows the human disposition to organise visual information as figure (central, in movement, affording action in a Gibsonian perspective) and background (peripheral, static, the Gibsonian visual invariants) that creates a mutable landscape produced by the attention of the perceiver [5], [12] . Hence, the proposed display, acting as a notification system [3], fades into the environment during routine sweeping and emerges at the centre of attention when a buried object is detected. So far, the design concept has exhibited a positive heuristic that allow us to proceed with the design process.

CONCLUSIONS

This paper presents a design for a visual display to be added to mine detection equipment. It is an application of the tenets of calm computing to a safety-critical system by putting cognition outside the mind, aligning inputs within the centre of attention and along the periphery, and juxtaposing stimuli in close proximity to the source of the information, all of which are designed to increase safety.

The redesign of a landmines detection device started with an investigation of the activities in which it is involved. We analysed the procedures isolated from James Staszewski for soil inspection with the metal detector PSS-12 in order to be taught to novices [1]. The attempt to embody these procedures into the system using well established psychological principles was the rationale that guided us in the redesign process. Then we asked three experts in the field of humanitarian demining equipment to provide hybrid evaluation/envisioning feedback which could the set requirements and constrain the following redesign iteration. Hitherto, we have individuated a spectrum composed of different elements in the analysed field: the sensory-motor activity and coordination, the landmine detector, working as a lens that disappears at the attention of the user, and the background environment. Ambient information systems can have, in this kind of configuration, a possible dimension, in which tools act as supports for creating relations and producing meaning from the heterogeneous stimuli available for the building of a perceptual experience.

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