Human factors guidelines for CCTV control center design introduction to a symposium

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Abstract. A CCTV system is a human-machine system, consisting of an observed reality, cameras, transmission, displays, image presentation, workplaces, and human information processing. A research project, including literature search, eight case studies and pilot experiments, showed a need for Human Factors Engineering guidelines for CCTV system design. There appeared to be two distinct areas of interest: surveillance/security versus remote control, which at least partially need different guidelines. A first draft of guidelines could be developed. However, there are several open items. The aim of this CCTV-Symposium is to discuss the open items 1) factors influencing perceived image quality, 2) the number of images presented per operator, and related to this 3) a task oriented concept for complexity of visual information, as well as a way forward to a HF CCTV standard.

Keywords. Closed Circuit Television (CCTV), control center, HF Engineering Guidelines, remote control.

1. Introduction

A CCTV-system (Closed Circuit Television system) is a human-machine system, consisting of an observed reality, cameras, transmission, displays, image presentation, workplace(s), and operator tasks including cognitive information processing. CCTV is used for traffic supervision, tunnel safety, object control (such as lock and bridge control), surveillance, security, remote process control, and so on. Regarding traffic supervision or surveillance, dedicated centralized control rooms emerged over the past decades.

There are well established Human Factors (HF) guidelines available for control center design in general (ISO-11064). However, CCTV is hardly mentioned (see section 2). An overview of general guidelines was presented by Wood (2007). Based on the observation of a lack of knowledge, a research project was initiated to determine the state-of-the-art on human factors of CCTV systems. The leading research question of the project has been: *What should an operator be able to see, detect, or read reliably on CCTV images? And therefore, what HF requirements should be met by the CCTV system?*

Draft HF guidelines for the design of CCTV control centers were developed (see section 3). However, several topics need further research and discussion. Therefore, the aim of this CCTV-Symposium is to bring together and discuss relevant issues as listed in section 4 of this paper.

2. Research

Nowadays, HF are a major issue in control center design. As HF Professionals the authors frequently came across CCTV systems for traffic supervision, tunnel safety, and surveillance. Also, the use of CCTV for remote control and process supervision is increasing rapidly. The multipart ISO-11064 *Ergonomic Design of Control Centers* offers a useful tool and often is a mandatory standard for control center design. However, as mentioned before, CCTV is hardly addressed. At first sight, the authors evaluate existing CCTV systems in control centers to be of a moderate or low quality. This evaluation was shared with other ergonomists as well as 13 companies and governmental organizations, and resulted in a research project. The project consisted of 4 parts, and a total of 160 days of research effort. The parts were:

1. Orientation and review of published guidelines and literature.
2. Eight CCTV Case studies, in order to gain insight in relevant CCTV tasks.
3. Some pilot experiments on image quality.
4. Development of Draft Guidelines.

During each project part, feedback was organized in a workshop format, with active contributions of all funding organizations. It was decided that the scope of the project would be limited to digital real time CCTV-systems. Moreover, the scope did not include legal and privacy related topics.

2.1 Literature review

Forty publications on HF of CCTV systems could be found and reviewed (Schreibers et.al, 2012; 2014, this issue), not counting papers on privacy aspects, legal matters, or how the public responds to CCTV. Very few references were found on remote control tasks, such as lock and bridge control, or remote process supervision of unmanned plants. In general, design guidelines consist of a list of "things you should think of". Some remarks:

- According to ISO-11064, large screen display technology or video-walls should primarily be used for shared information. In practice, many CCTV control centers have "individual" video-walls. No manufacturer independent HF recommendations could be found on the application of video walls.
- The number of images (or live streams) an operator can handle depends on task complexity. Some sources mention a maximum of 12-16 images at a low task complexity, however without giving a clear definition on task complexity.
- Usually, operator workload is given as a camera/monitor-ratio or a number of screens per operator. This guideline is not task related and may depend on display technology.
- Experimental evidence within all literature sources is thin. A few field studies have been published in the UK (Wood, 2007) concerning traffic control (checking hard shoulders), rail safety (level crossings), and incident detection in shopping areas.

2.2 Case studies

After the literature survey, eight case studies were executed. The cases concerned a traffic supervision center, two surveillance centers, two security centers for controlled entrance, remote Jetty supervision, a ship's bridge, and lock control. The purpose of the case studies was to gain insight in CCTV operator tasks and current CCTV instrumentation.

Each situation has been analyzed systematically by experienced HF Professionals using a standardized task analysis protocol. The on-site analysis consisted of two visits to establish the situation (drawings, technical data, photographs), observe operator task performance, and to have semi-structured interviews with operators.

Schreibers and Bouchier (2014) contributed a symposium paper on traffic supervision. After the initial task analysis, the large screen display of a highway traffic supervision workplace was replaced by a new large screen display. The overall display size and viewing distance both were enlarged, display resolution was reduced and brightness increased (by 100%), resulting in a poorer overall image quality. However, the operators value the new situation as a substantial improvement. This also indicates the need to better understand *perceived* image quality.

2.3 Experiments - perceived image quality

Research published on image quality reduction is scarce and largely directed towards the technical features of the CCTV system. From several features, such as coding, transmission, decoding, and scaling of images it is not clear what the exact impact on the perceived image quality is. In practice one often can see bad quality images, reduced sharpness (sometimes due to scaling of the native camera image), bad contrasts, etc. The quality of newly delivered CCTV systems may be tested with test charts and test procedures as developed by Aldridge & Gilbert (Rotakin manikin; 1996) and Damjanovski (Vidilabs test chart, 2005). Image quality is, for example, linked to images of people. Question: to what extent do other cognitive features of human perception influence the judgment of image quality. It also is questionable whether one quality requirement suffices. We see at least four operator tasks, monitoring, detecting, recognizing, and identifying, appealing to different image qualities. Moreover, we distinguish at least two opposite areas of interest:

1. Surveillance and security systems; research focus is on image reduction in view of limited transmission capacity relative to a large number of camera views one would like to transmit (see for example Keval, 2007).
2. Application areas, where image reduction and quality degradation are not an issue, because lossless systems are assumed. For example: lock and bridge control.

The findings from literature on image quality and our practical experiences led to experiments regarding the use of test charts. In a laboratory setting, direct view was compared with mediated images (camera - transmission - display) for the Vidilabs test chart, and the Rotakin manikin. As a third test, a much simpler system is used, namely the Landolt C visual acuity test chart, which is widely used by opticians (Bennis, et.al, 2014, this issue). Subjects were tested in various conditions. Conditions were: mediated vision versus non-mediated vision, different viewing distances, and different levels of ambient lighting. Two experiments were done. The results are not very consistent yet (see Bennis et.al, 2014). However, it was clear that the Rotakin test did not provide sufficient unique distinctive characteristics to be deployed as a valid test system. For the measurement of image sharpness the Landolt C test turns out to be a simple and adequate test system.

At the time of writing this paper some follow up experiments are being developed, investigating: (a) the influence of contrast and brightness, and (b) the role of scene perception. The Rotakin test will no longer be used. The difference between the Vidilabs and Landolt C approach, as well as between the issues (a) and (b) will be related to the viewing tasks monitoring, detecting, recognizing and identifying.

3. Draft Guidelines

Only a few standards on HF and CCTV systems could be found (EN 50132-7, 2012; FHWA-US department of transportation, 1999). In addition, several research projects have been announced in the UK, however results are not available or hard to get. The ISO-11064 standard on the design of control centers provides a clear structure for design requirements, however does not include CCTV. It was decided to adopt the ISO-11064 structure for the development of Draft HF Guidelines. An overview of the content is given below:

1. Project Ergonomics – the engineering process for integrating HF in the design of CCTV-related control centers.
2. System Description – describing the elements of the CCTV system and how to achieve a complete functional description including a detailed information analyses.
3. Tasks and jobs – CCTV operator job content, workload, and work organization issues.
4. Control center layout and workplace design – Requirements for control center layout, workstation design and visual anthropometry for situations with a large number of information displays (i.e. hardware issues).
5. Image presentation and interaction design – for CCTV systems, the majority of information concerns camera images. This chapter includes guidelines on information (i.e. image) display, image quality, navigation, and picture design including hybrid graphics (images and other types of information).

A 70 page draft guideline document was published (Pikaar, et.al, 2013) and being tested by the 13 project partners. For example, Reinstra and de Groot (2014, this issue) applied the guidelines for the design of remote bridge control, including determining the number and locations of camera's for remote bridge control.

A part of the draft guideline document concerns standard control center ergonomics, such as guidelines for workstation measurements, work environment, or legibility of text. The evidence level for these guidelines is high. On the other hand, lack of solid evidence and some grey areas were encountered regarding the following topics.

- There are contradictions between case studies and literature. In practice the number of CCTV images presented to one operator may be considerably more than the "12-16 images guideline" found in literature. The case studies indicated that users usually don't have a problem with this (Reinstra & de Groot, 2014, this issue).
- There is little understanding of factors influencing the perceived image quality. The validity and practical use (instructions) of test charts should be reviewed.
- Image complexity is not very well understood. Evidenced guidance on the relationship between image complexity and operator mental workload is not available. Do we know e.g. how movement within images contributes to the level of complexity?
- Task complexity is related to operator education, training, and experience. The case studies showed large differences in operator education. An impact on guidelines for task complexity, information structuring, and so on, should be expected, however, could not be found in literature.
- To describe the content of CCTV-images, the "concept of scenes" has been introduced. A scene is defined as a logical and meaningful set of visual information, to be monitored with a specific aim. This concept might be useful to address CCTV task complexity, nowadays indicated by the variables "camera-operator ratio" and "camera-monitor ratio". The operator task determines the composition of a scene. For example: for tunnel safety monitoring a series of images representing one traffic direction could be defined as one scene. For a monitoring task, the operator could handle four tunnel tubes, i.e. four scenes; each scene consisting of several individual images. Once an incident occurs (event), the

scene changes. The operator task requires more detailed images of the incident area. For serious incidents, workload may become high and (in practice) a colleague is asked to monitor the remaining tubes.

- Some topics not being part of the research scope, are now expected to contribute considerably to CCTV control centers. It is suggested to develop guidelines on automated video content analytics (VCA), post-event analysis of CCTV footage, and special types of cameras (infra- red, high resolution).

4. Discussion

Technology for control center instrumentation and for CCTV-systems is rapidly changing and new applications are emerging. HF research tends to be late. Laboratory experiments, field experiments and theory development take considerable time. Therefore, we decided to publish Draft Guidelines, being fully aware that the guide would not be complete, and scientific evidence might be lacking. Johnsen and Stene (2014, this issue) indicate the importance of CCTV for remote support of oil and gas platforms. In addition, they ask: *should there be a set of guidelines, rules or best practices to support the implementation and use of CCTV?* The paper by Bennis and Lenior (2014, this issue) introduces the combination of CCTV and other ICT support (sensors) as well as an application area not being addressed elsewhere in CCTV literature (i.e. healthcare).

During the Symposium, we propose to discuss:

1. the need for HF guidelines for CCTV (in) control centers, i.e. is there consensus on our finding of low quality CCTV workplaces and the proposed road to improvements.
2. the state-of-the art on CCTV research, i.e. a lack of evidence for the (sometimes) mandatory requirements, as well as test procedures; did we miss literature, research and experiences/case studies?
3. whether our view on important research issues is supported, i.e. open items: 1) factors influencing perceived image quality, 2) the number of images presented per operator, and related to this 3) a task oriented concept for complexity of visual information and operator workload;
4. discuss the way forward to a CCTV Human Factors Standard.

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