Security Journal, **2008**, (1–21)

www.palgrave-journals.com/sj

"Not the Usual Suspects": A Study of Factors Reducing the Effectiveness of CCTV

Hina Keval and Martina Angela Sasse
Department of Computer Science, University College London, Malet Place Engineering Building, London WC1E 6BT, U.K.
E-mail: h.keval@cs.ucl.ac.uk

Previous research on the effectiveness of Closed Circuit Television (CCTV) has focused on critically assessing police and government claims that CCTV is effective in reducing crime. This paper presents a field study that investigates the relationship between CCTV system design and the performance of operator tasks. We carried out structured observations and interviews with 13 managers and 38 operators at 13 CCTV control rooms. A number of failures were identified, including the poor configuration of technology, poor quality video recordings, and a lack of system integration. Stakeholder communication was poor, and there were too many cameras and too few operators. These failures have been previously identified by researchers; however, no design improvements have been made to control rooms in the last decade. We identify a number of measures to improve operator performance, and contribute a set of recommendations for security managers and practitioners.
Security Journal advance online publication, 6 October 2008; doi:10.1057/sj.2008.2

Keywords: CCTV control room; security; task performance; human–computer interaction; ergonomics

Introduction

Closed Circuit Television (CCTV) technology has advanced dramatically over the last few decades, and these advances have led to an increasing number of CCTV deployments for a wide range of security goals. But what is missing so far is an understanding on how CCTV technology has to be designed, deployed and operated to support specific security goals, and what tasks human operators who work with CCTV have to carry out to attain the goals.

There have been previous studies of operators in control rooms in a range of work environments, such as power plant control rooms (Norros and Nuttinen, 2005), air traffic control centres (Bentley *et al.*, 1992; Twidale *et al.*, 1994), ambulance control rooms (McCarthy *et al.*, 1997; Blandford and Furniss, 2006), and within a London Underground control room (Luff *et al.*, 2000). There has been only one study conducted within a security control room (Gill and Spriggs, 2005; Gill *et al.*, 2005). This study looked at the characteristics of CCTV systems and their impact on the effectiveness of CCTV against crime and reducing crime. A number of important factors that reduced the CCTV operator's job were found; however, the technical factors that hindered operator performance when performing tasks were not examined in great detail.

This paper presents a field study that investigates the relationship between CCTV system design and the performance of operator tasks. We used contextual inquiry (Beyer and Holtzblatt, 1998) – a process in which structured observations and interviews are used in the field to learn how users work and interact within their workplace. This involved interviewing 13 CCTV control room managers and 38 CCTV operators. We then observed operators at work and asked probing questions during tasks. The aim of our field studies were:

1. To gain an understanding of the tasks and contexts for which CCTV is used within a control room environment.
2. To evaluate the effectiveness of CCTV and other technologies used by control room operators to support their security tasks.
3. To identify the technical and social constraints for operator tasks and activities, and the possible conflicts between different CCTV stakeholders in and out of the control room.
4. To contribute a set of recommendations for security control room owners and practitioners to improve the effectiveness of CCTV use in security control room environments.

We begin with a review of previous research on the effectiveness of CCTV, and studies within other control room environments. Following this, we present the results from our field study which we then discuss the implications for the design of CCTV systems. We finish with a set of recommendations for improving the effectiveness of CCTV.

Previous research

Luff *et al*. (2000) conducted a naturalistic field study in a London Underground CCTV and dispatch control room, to see how control room staff used different technologies to support their everyday work activities. They investigated how operators monitored their surrounding domain and colleague activities using different tools and systems. Luff *et al*. found that the task of monitoring CCTV was affected by poor positioning of cameras. Some camera views were not clear, as they were covered in train brake dust, were out of focus and had a "burnt-out" appearance for unknown reasons. Technology was difficult to manage because there were many separate systems which should have been integrated. Luff *et al*. proposed recommendations, which included integrating information sources, making relevant station information accessible to operators in different locations and the use of a touch-screen interface to allow cameras to be displayed instantly on monitors in the control room.

McCarthy *et al*. (1997) conducted a field study in an ambulance control room. Operators were interviewed and observed to understand how they located camera scenes using CCTV, communication tools and maps when dispatching ambulances. The study involved the evaluation of a computer and communication system at one ambulance control room, for the possible deployment into another control room. McCarthy *et al*. identified a number of communication problems when callers reported incidents over the phone. For example, information was poorly delivered when callers needed an ambulance because of their strong

accents, delaying ambulance dispatches. Also, callers (unintentionally) gave poor descriptions of their location when an ambulance was requested. Controllers were also poor in responding to calls, as they lacked experience in identifying camera scenes quickly.

Ambulance control rooms operate similarly to CCTV control rooms – since both settings involve a number of operators monitoring and responding to incidents on the outside with the support of CCTV, maps and communication tools. Although ambulance operators used radio and CCTV video and monitoring systems to locate scenes, McCarthy *et al*. did not examine the effectiveness of the technology and instead examined the communication factors that affected the task.

A national study on the effectiveness of CCTV was conducted for the U.K. Home Office (Gill and Spriggs, 2005; Gill *et al*., 2005). In this study, observations and interviews were carried out at 13 public-space CCTV control rooms, which were set up under the Home Office Crime Reduction Programme. At these control rooms, the activities from public CCTV cameras were monitored by CCTV operators with the support of artefacts such as Pan Tilt, and Zoom (PTZ) camera controls, computer systems, telephones and radios. Various aspects of the control room operations were examined, such as ownership, design, management, working practices, communication, operator pay and training, as well as the processing of CCTV evidence. Although the study did not examine the impact of specific technologies on the operator's task performance, a number of technical failures affecting task performance were identified. For instance, it was found across several control rooms that there was a very high camera-to-operator and camera-to-monitor ratio, which reduced the "…probability of spotting an incident or providing usable recordings" (p. 8). It was also found that video in control rooms which recorded analogue video was very poor quality because the tapes were being re-used too often. At the control rooms which recorded digital CCTV, the recording quality of the video was also very poor. In terms of temporal quality, Gill *et al*. found that many systems were recording video at half a frame per second[1] (fps). In two cases, the frame rate was low as ¼ fps and at one of these control rooms the video quality was so poor the evidence could not be used for investigations and the police described the video as "virtually useless". Gill *et al*. found that the recording rates were chosen based on the equipment purchased by management and the equipment was purchased based on their budgets and advice provided by consultants.

Ten out of the 13 control rooms Gill *et al*. studied used analogue technology to record CCTV and at these control rooms very few used other systems which were digital. Since this study, CCTV technology has advanced, and many systems are now mainly operating using digital and networking technology, and since these changes there have been no research on how CCTV operators perform their security tasks using digital technologies within the control room.

Control room field study

The aim of the study presented in this paper was to assess the effectiveness of CCTV and other technologies that are currently used in CCTV security control rooms. Previous

[1] Unlike analogue video, digital CCTV video can be recorded at different levels of temporal quality, and the parameter for this is termed frame rate. The maximum frame rate for video is 25 frames per second (fps), which means that there are 25 individual pictures per second of a scene.

research by McCarthy *et al.* (1997), Luff *et al*. (2000), Gill and Spriggs (2005) and Gill *et al.* (2005) uncovered some of the performance issues within control room environments; however, the work has not provided a systematic examination of security tasks where digital technology is used. Also, previous research has not considered the implications of the problems identified in relation to operator tasks. In our control room study, we sought to provide an understanding of security tasks performed by CCTV operators as we found that there is no description of this in CCTV literature – particularly for those who are using digital technology. Early findings were reported (see Keval and Sasse, 2006).

Method and procedure

The field study we conducted took place between September 2005 and April 2006, and involved 13 individual visits to 13 CCTV control rooms, lasting approximately 4–5 h per visit. When organising the visits, best effort was made to attend the control rooms when a maximum numbers of operators were working on a shift, to gather as much insight as possible. This was however not a strict criterion, as we were also interested in understanding how operators performed when the control room was short-staffed. The visits were arranged via the U.K. CCTV user group. All of the CCTV control rooms visited were based in London, and one was at one of the largest and busiest London airports. 2/13 control rooms were based in towns south of London, and 3/13 were police CCTV control rooms (one of which was the airport control room). The remaining control rooms were managed either by a local authority or by a private company on behalf of the local authority.

The three police control rooms we visited operated similarly to a public or private managed CCTV control room. However, the main differences were that the operators working within police control rooms were trained in policing as well as CCTV, and also had a higher authority and therefore better access to resources and people. Unlike CCTV operators, police operators did not need to share their CCTV video sources with other control rooms.

Contextual inquiry (Beyer and Holtzblatt, 1998), a participatory technique used in systems design, was applied in this study to identify the security goals and tasks, to examine how CCTV and other systems were used, and to understand the interactions between CCTV users. This method consists of number of field research techniques to develop a rich understanding of the work practices within the user's workplace. The same steps are carried out for field observations and interviews; however, a natural dialogue is maintained with the users during the analysis, without forming bias or influencing their tasks and activities. We focused our observations on the how operators performed their tasks and how different artefacts were used when completing their tasks. We chose the two following field methods to achieve this: (1) semi-structured interviews: with control room managers and operators during task performance and (2) direct observations (Johnson, 1993) with CCTV operators in the control room.

Prior to each visit, the manager was provided with the objectives of the field visit, as well as the planned structure and details of the visit. This plan included: a guided tour of the control room and other facilities, an interview with the manager and 4–6 h of continuous

observations with operators in the control room. The entire fieldwork was completed by the first author of this paper. For the interviews, managers were asked the following questions:

1. What are your goals for CCTV at your control room?
2. What type of crime is observed at your control room?
3. How many operators work at the control room in one shift?
4. What shifts do operators work?
5. What type of technology is used in your control room to store and transmit video (digital or analogue, or both)?
6. How many cameras do operators use to monitor the surveillance areas?

We systematically recorded specifics of the control room technology, operator tasks and usability problems. These notes were guided by the use of an observation checklist (see the Appendix), which included a number of explicitly defined behavioural and technical questions to prompt the researcher while interviewing and recording the observations. The items on the checklist were decided based on our study aims.

Results

Analysis

Our analysis assumed that the responses provided by managers and operators were honest and accurate. The identities of the control rooms and staff members interviewed and observed were disguised to preserve anonymity. Following the visits, we gathered the notes and created a large affinity diagram[2] to identify and categorise the main issues. The diagram was created by organising the individual observation and interview notes captured from the fieldwork sessions into hierarchical order. Visually it was possible to identify the common issues and themes as well as the scope and severity of each usability issue. This analysis method was taken from the wall method proposed by Beyer and Holtzblatt (1998).

Findings

We were able to identify the different stakeholder groups who belonged to the CCTV security system, and collaborated with operators using radio and telephone communication (see Table 1). It was important to identify all of the CCTV stakeholders in order to identify the completeness of the security goals, and their tasks which involved the interaction with other stakeholders working within the security system.

Starting with the stakeholders at the bottom of Table 1, we observed operators liaising with local authority employees to report and provide feedback on housing and public safety issues. This was achieved through telephone or e-mail rather than radio communication.

[2] The purpose of creating an affinity diagram is to organise the brainstorm of topics identified from the observations logically into groups, and then define their labels into meaningful categories. This process helps clarify large and complex issues and then organise the findings into a structural fashion.

Table 1 CCTV stakeholders and their roles identified from the field study

CCTV stakeholders	*CCTV stakeholder roles*
Control room manager	• That all CCTV operators and team leaders operate all equipment and cameras to comply with CCTV code of practice. • Monitor and patrol via view-screens and to take any remedial or immediate action and notification appropriate to events seen. • Operate radio communication equipment and any other tools and equipment. • Liaise operationally with police. • Coordinate a response to detected incidents. • Ensure communication between other customer departments, external agencies or the public in a professional and courteous manner at all times. • Manage CCTV operators and team leaders. • Compile statistical reports for management.
Control room team leader and operators	• Operate all equipment and cameras to comply with the control room policies, and CCTV code of practice. • Monitor and patrol via view-screens effectively and to take any remedial or immediate action and notification as appropriate to events seen on CCTV. • Liaise operationally with police and to coordinate a response to detected incidents, including the use of shared CCTV monitors. • Record all events and actions taken in a clear, legible and accurate written format and to record these onto any other video media when required. • Monitor and patrol via view-screens effectively and to take any remedial or immediate action and notification as appropriate to events seen. • Manage the production of evidence by CCTV operators from the initial telephone call or visit by an applicant through to the completion of the statement and bagging of the evidence.
Police officers/inspectors	• Communicate with police control room and CCTV control room staff about incidents on-street. • Provide feedback to operators with regard to incidents using communication systems (i.e. radio/telephone).
Police control room operators	• Use police radios to contact control room operators for incident support using CCTV cameras.
Participant CCTV radio users	• Use shop and pub watch radios to contact control room operators for reporting suspicious and actual incidents on-site. • Provide descriptions and locations of incidents and targets to facilitate operator search tasks.
Local authority employees	• Report with council on maintenance and public safety maters to control room operators.

When operators reacted to crime on-screen, they communicated with local businesses such as the high street shops, clubs and bars (these are known as the participant CCTV radio users). These users subscribed to the CCTV scheme and exchanged information about incidents using a two-way radio. Operators also collaborated with their local police department to gather up-to-date information about crime occurrences in the surveillance areas.

This communication was achieved through face-to-face meetings, e-mail and fax. The method of contact depended on the urgency of the information.

Local police officers often visited the control rooms to leave photographs of suspects to assist operators when performing proactive surveillance. The communication and collaboration between operators and police control room operators was very strong. CCTV operators were responsible for contacting the police control room so the police were able to dispatch the right number of police officers to attend the scene. Operators initiated contact with police operators only when they very certain about an incident. Once contact was made, CCTV operators would share their monitor views with the police operator to track the target/vehicle in real-time purposes. Maintaining a good level of communication between CCTV operators and police control room staff was crucial for attending to crime incidents, and this was achieved very well.

Each of the managers' goals for CCTV (question 1) is summarised in Table 2. Across the control rooms, the general goals for CCTV were very similar – which was to use CCTV to detect crime and prevent crime occurring in public places. The specific goals however varied between control rooms and these goals depended on the surveillance areas, levels and type of crime, and the amount of funding each control room had for security. The typical crime

Table 2 Characteristics of control rooms observed

Control room	*Manager goals for CCTV*	*Technology*	*C2O[a] ratio*
1	Traffic enforcement and surveillance	Analogue 50% Digital 50%	160:5
2	Monitor incidents and crime	Analogue 100%	110:4
3	Prevent crime and protect the public	Digital 100%	90:3
4	Review images on behalf of police	Analogue 30% Digital 70%	111:6
5	Provide council support and surveillance	Analogue 30% Digital 70%	200:4
6	Deter and detect crime assist in identification, arrest and prosecute of offenders, reduce fear of crime	Analogue 100%	141:3
7	Catch criminals, track lost and stolen vehicles, traffic enforcement, emergency resources for residents	Digital 100%	110:3
8	Deter and detect crime, support borough for emergencies support police operations	Digital 100%	87:3
9	Prevent crime and catch criminals	Digital 100%	80:1
10	Work with adult community service and community section to provide safety and support using CCTV	Digital 100%	120:1
11	Crime and disorder reduction, interception and arrest of offenders, provide elderly support using call centre and alarm support services.	Digital 100%	96:3
12	Public safety, supporting police officers and operators in operations and incidents	Analogue 100%	108:2
13	Prevention and detection of crime, traffic management, public re-assurance, provision of evidence for civil & local proceedings	Digital 100%	65:2

[a]C2O, camera to operator.

observed at the control rooms (question 2) included gun crime, violence, theft, cash machine robberies, shoplifting, graffiti, car crime, underground ticket touting, burglary, fly tipping,[3] breaking traffic rules, street robberies, drug dealing and drug abuse. The type of crime observed in London was wider spread than in the control rooms further away and included a higher number of violent and drug-related crimes. Outside London, the most prevalent crime included property theft, shoplifting, damage, burglary, anti-social behaviour and some drug dealing.

On average; five operators worked on a shift (question 3). All of the control rooms operated live surveillance for 24 hours, and operator shift patterns generally consisted of: 12-h day shifts for 4 days with a 2-day break, and then a 12-hour shift for four nights (question 4).

A majority of the control rooms we visited used 100 per cent digital technology (7/13) to record CCTV video, 3/13 used 100 per cent analogue and 3/13 were in the process of upgrading from analogue to digital (question 5). Analogue CCTV systems work by transmitting and recording video in analogue format. The video signals were therefore transferred via radio or microwave fibre link directly to the control room for real-time viewing, and were recorded onto VHS tapes and archived in the control room for approximately 1 month. Where both analogue and digital technology was used for video transmission and recording, operator tasks were no different except for the way the video was recorded. The camera-to-operator ratio figures in Table 2 (last column) shows that were far too many cameras and too few operators across all of the control rooms we visited (question 6).

CCTV operator artefacts and tasks

Figure 1 shows the typical layout of a CCTV operator's workstation and their workstation environment. The different artefacts used (both technology- and paper-based) by operators are depicted in Table 3. Managers were asked further questions about the tools operators used. We found that 4/13 control rooms used an interactive mapping and database system, to help operators search and locate the cameras with the use of a PC-based geographical map and database system. At the remaining control rooms (9/13), a paper list was used detailing the cameras connected to the system. This list was organised by camera name/number and location. In addition to the paper list, a paper map of the surveillance area was used to find the cameras geographically with a camera selection interface. At 6/13 control rooms, an electronic map of the surveillance area was accessible via the operator's personal computer, and at one control room an automatic number plate recognition (ANPR) system was in use to automatically alert operators on lost and stolen vehicles which passed specific ANPR cameras. This tracking tool worked by automatically alerting operators by sound which then displays the suspect's vehicle (a CCTV image), with an electronic match of the vehicle registration number and the vehicle alert type.

Following the interviews and observations, it was possible to identify the main tasks operators performed. These tasks were (1) proactive surveillance; (2) reactive surveillance

[3] Fly tipping is a term used by council and control room staff where the individuals are seen illegally dumping rubbish in public places.

Figure 1. Typical set-up of a CCTV operator's workstation.

and (3) CCTV video review and tape administration. Table 4 summarises these tasks with the estimated ratio of time spent on these tasks and the artefacts used.

(1) *Proactive surveillance* requires operators to "spot" suspicious behaviour and individuals by scanning activity across several cameras using the monitor wall or by inspecting camera by camera on their inspection (spot) monitor(s). This task was in general carried out during what operators refer to as the "grave-yard shift" (the early hours of the morning shift between 4–7 am and all day on Sunday). Operators reported that they would scan activity on the monitors at random along the monitor wall, and did not use any pattern of scanning. Operators said that they knew where to look but could not explain how and why. One operator said, where they scanned was "… based on intuition". Another operator commented that, "…it was like sixth sense, and I don't know where I should be looking as anything could happen at any time…er… I can just tell something is going over there even though no-one tells me".

(2) *Reactive surveillance* requires operators to react to audio or visual cues about incidents mainly on radio and phone and sometimes via e-mail, fax and through face-to-face communication. These tasks are typically carried out during busier periods of the day. Following an alert, operators were observed locating scenes in two ways: (1) by entering the camera number into the touch screen interface/keyboard controller or (2) by inspecting activity on monitors along the monitor wall. Many operators said that "… a large proportion

Table 3 Artefacts used to support security tasks, number used per operator and their functions

Control room artefacts	*Number of items per operator*	*Artefact functions*
Monitor wall	5–40	• Proactively monitor camera activity. Search and select one or more CCTV views onto the spot monitor for close up inspection.
CCTV spot monitor	1–5	• View CCTV views directly on desk mounted monitors selected from monitor wall for close-up inspection.
Camera controller: pan, tilt and zoom	1	• Adjust the views of interested scenes to gain better visuals.
Camera controller: keyboard and user interface	1	• Enter camera numbers and adjust picture quality to gain better visuals.
Personal computer connected to the Internet	1–3	• Alter imaging properties of the camera view to improve visuals. • Access of e-mail, the intranet, and also review of CCTV.
Interactive mapping and database system	1 (only present at 4 control rooms)	• Access geographical maps showing locations of cameras and other relevant mapping data (i.e. telephone box locations).
Automated surveillance systems	1–2 (shared) (only present at one control room)	• Automatic number plate recognition (ANPR). • Body tracking. • Facial recognition systems.
Evidence reviewing monitors	1–2	• Replay of video footage for verification by operators/police.
VCR/CD/DVD recording devices	1–3	• Create working copies of CCTV footage for the police.
Pub and shop watch radios	1–3	• Radio users to report incidents to control room.
Police radios	1–5	• Relay crime incident information between operators and police control room.
Telephones	1–3	• Receive incoming calls from public and council departments on security matters.
Incident and handover logging book	1	• Log crime and traffic incidents.

of video evidence is generated as a result of the police radio contact and very little is used following an incident from recorded footage".

(3) *CCTV video review and tape administration* tasks were carried out during the quieter periods of the operator's shift. This task consisted of:

1. Logging all incidents observed into a database, spreadsheet or into a log book.
2. Preparing working copies of CCTV video footage for the police and other CCTV users such as the traffic enforcement department.
3. Labelling and bagging of CCTV video evidence for the police.

We did observe these tasks, as they were carried out in a separate room to the control room. When operators were asked about these administrative duties, they were described as dull, boring, mundane and lonely work – and not as interesting as working with real-time CCTV.

Table 4 Summary of operator tasks, time spent and artefacts used

Task	*% Time allocated*	*Artefacts used for task*
[1] Proactive surveillance	Day shift: 60	For scanning CCTV views on a single monitor: [1] PTZ camera controllers (1) [2] Touch screen interface/keyboard controller to select camera number for view (1) [3] Spot monitor – a desk facing video monitor (1–2)
	OOH[a] shift: 30	For scanning CCTV views on several monitors: [4] Monitor banks (10–40)
[2] Reactive surveillance	Day shift: 30	[1] Police CAD[b] Radio (1) [2] Digital/Analogue shop/pub watch radio (1–2) [3] PC (1) [4] Telephone (1–3)
	OOH shift: 65	[5] PTZ controls (1) [6] Spot monitor (1–3) [7] Monitor banks (10–40) [8] Automated system (1) [9] Paper map or GUI map (0–2)
[3] CCTV video review and administration	Day shift: 10	[1] PC with playback review software (1–2) [2] Media for recording copies (unlimited) [3] Paper work for logging data
	OOH shift: 5	[4] Tape/CD/DVD labels [5] Evidence bags

[a]OOH, out of hours: Weekend and night shifts.
[b]CAD, computer-aided dispatch is a radio system used by U.K. police operators and CCTV control room staff.

Usability issues identified at control rooms

Using the observation checklist we noted any usability issues concerning operator shifts, tasks, workstation set-up, artefact usage, situation awareness and the processing of CCTV video footage. These usability issues were then categorised into common themes by putting together a large affinity diagram. This diagram was created by transferring the findings onto post-it notes, and placed into categories onto a large wall space. Table 5 summarises the usability issues, stakeholder conflicts and the severity ratings for each of the issues identified. The most severe usability issues were assigned a rating of 1 and these are highlighted in bold in Table 5. The severity ratings were decided following discussions with the control room managers (separately) after the study was complete. The severity related to the impact of the problem when detecting or preventing the crime, as well as the risk of committing an error in the task.

In this section, each usability issue identified is discussed in the order given in Table 5. For each issue, we provide recommendations for improving the effectiveness of CCTV.

(1) CCTV Camera position issues:
(1a) *Cameras located in low-crime areas:* At 6/13 control rooms, we noted that some of the cameras were very old (over 10 years) and the older the cameras were ignored.

Table 5 A summary of usability issues, stakeholders affected by the conflict and the severity of issue

Usability issues	*Stakeholders affected by conflict*	*Severity*[a]
(1) CCTV camera position issues		
(1a) Cameras located in low crime areas	Operator and radio users	2
(1b) Blind spots	Operator and radio users	1
(1c) Trees and bunting	Operator and radio users	1
(1d) Camera signals affected by poor weather	Operator and radio users	1
(1e) Faulty equipment	Operator and radio users	3
(1f) Pointing cameras in bad positions	Operator and police operators	2
(2) Ineffective workstation set-up		
(2a) Lack of space	Operator only	2
(2b) High camera-to-operator ratio	Operator and police operators	3
(3) Difficulty in searching and locating scenes		
(3a) Lack of familiarity with surveillance areas	Operators and police operators	2
(3b) Lack of integration of information sources	Operators and radio users All users	1
(3c) Ordering of cameras in database/paper list		3
(4) Poor quality video recordings		
(4a) CCTV video recorded at very low temporal and spatial resolution	Police staff	1
(5) Communication difficulties		
(5a) Noise levels	Between operators	1
(5b) Too many audio sources	Between operators	2
(5c) Poor communication between radio users	Operators and radio users	3
(5d) Radio tools faulty	Operators and radio users	2

[a]Severity scale: 1 – Very serious; 2 – Serious; 3 – Moderate; 4 – Minor and 5 – Extremely Minor.

Operators stated that many of the old cameras showed areas where no activity took place, that is, shops that were no longer in business, and housing which had been knocked down. One operator commented that, "… 9/10 times, nothing happens on these cameras…this is quite annoying as I could think of plenty of places to re-locate them".

(1b) *Blind spots:* Operators showed the researcher the cameras that revealed blind spots. These are areas of the scene which are invisible due to incorrect camera positioning or as a result of obstructions to the camera.

(1c) *Trees and bunting*: In the leafier boroughs, a number of CCTV cameras were out of use because overgrown trees and foliage had occluded camera views. Operators also said that festive and carnival bunting put up by the council often blocked camera views. Camera functions were also affected by the constant movement of bunting causing camera lenses to auto-focus. One manager commented on this issue saying that, "…it was down to one government department not talking to another, and this was because the planning section within the council would not allow trees to be cut down because of their restrictive environmental policy".

At control room 10, the council maintenance department would not cut down or prune trees and plants in the town centre. The manager at this control room explained that he was left with no choice but to install another CCTV camera in the same location, but in front of the tree which obstructed the old camera, to get around the problem. Operators said it was important that they did not lose sight of any camera especially in the crime hot spot areas.

(1d) *Camera signals affected by poor weather*: At 6/13 control rooms, operators were distressed and frustrated when camera signals (analogue) were lost or disrupted temporarily as a result of bad weather conditions. This was observed on three visits at two control rooms when there was heavy rain and wind. During signal loss, operators complained that maintenance and repairs took too long which was very annoying for operators when working with these cameras. Some operators found this disruption a good opportunity to take a break.

(1e) *Faulty equipment:* Some operators were unable to access CCTV cameras because of constant equipment failure. At 3/13 control rooms, two camera controllers were broken which caused serious problems when operators carried out proactive surveillance when following a target or vehicle of interest on their spot monitor. One operator "felt quite embarrassed" when sharing real-time video with police control room operators during an incident because they were unable to move the CCTV camera left to right when asked to because the controls were broken.

(1f) *Pointing cameras in bad positions*: Operators on previous shifts would leave the cameras in "useless" positions, that is, facing the road or sky, or out of focus which meant that their colleagues lost valuable time in re-positioning cameras. Operators were asked why their colleagues did not re-position the cameras properly, and most said it was down to laziness, carelessness and because they played with camera controls when bored.

(2) Ineffective set-up of operator's workstation:
(2a) *Lack of space:* Operators showed signs of physical discomfort and visual strain due to the poor set-up of artefacts. At 6/13 control rooms, operators reported that they were unhappy with the physical set-up of their work environment. Workstations were altered frequently due to the system upgrades taking place in the control rooms. Where upgrade work was in progress, old equipment and tools such as video cassette recorders, printers and video monitors were left lying under operator desks and on shelves, which cluttered the operator's work environment. One operator said, "I would like the old stuff taken out and less clutter under the desks…I can hardly move my feet".

At the local authority control rooms, managers said that a lot of paperwork needing filling out in order to remove old equipment and nobody could spare the time to complete the paperwork so it never got done. At control room 12, the manager said, "…I don't think the workstations meet health and safety standards, there's too much twisting and turning, and operators obviously don't have enough space".

(2b) *High camera- to-operator ratio*: As shown in Table 2, the number of cameras linked to the control rooms was very high for the number of operators on shift. Many operators complained that more and more cameras were being added to the system, and felt overwhelmed by the number of cameras they had access to. Operators found that learning the entire list of cameras took a new member of staff several months and it was difficult to locate and keep track of every camera. Managers saw this as a temporary problem related to staff shortages.

(3) Difficulty in searching and locating scenes:
(3a) *Lack of familiarity with surveillance areas*: Most operators did not reside in the surveillance areas and found it hard to familiarise themselves with the area when they started their job. At 3/13 control rooms, operators new to the control room were given hand-drawn geographical maps of the surveillance area. The maps were drawn with the camera icons and numbers at their relevant locations. These maps were drawn by experienced operators who felt that they should help newcomers to get them up to speed with the tasks. Experienced operators rarely used maps as they knew the locations of a majority of the CCTV cameras in the system.

(3b) *Lack of integration of information sources:* At 9/13 control rooms, operators located camera scenes using the camera controls, a spot monitor and the paper lists of cameras connected to the system. Once the street and camera ID was located on the list, the operator would then enter the camera ID into their systems to retrieve the video scene on their spot monitor for close-up inspection. If necessary this view is then shared with police operators for immediate support. This task involved the use of separate tools which was inefficient. At 4/13 control rooms, an all in one interactive mapping and database system was used. The observations showed that operators responded faster and showed greater confidence when carrying out their tasks using this system.

(3c) *Ordering of cameras in database/paper list:* Operators complained about the illogical numbering and ordering of cameras within the camera lists (paper and electronic). One operator said that "… new cameras were good [in terms of image quality] but hard to find; [they were] not placed in any proper order and would be annoying at times". Operators had a personal camera favourite based on how good the image quality was and how well they were positioned – which made their surveillance tasks easier.

(4) Poor quality video recordings:
(4a) *CCTV video recorded at very low temporal and spatial resolution:* Operators felt that the quality of recorded video produced at the control room was very low. This issue was observed at control room 9. The police at the time of the observation was investigating a theft incident. The operator showed the researcher a recording which showed a potential suspect near to the store where the incident took place. The CCTV video was recorded by the control room digitally at 1 fps. The camera was not well positioned, and the recorded quality was too poor to discern the actions of the potential suspect. The footage of the incident was taken at night, which made it even harder to identify the actions of the thief. These conditions made it impossible for the local police to use the CCTV video for theft investigations, never mind criminal prosecutions.

Control room staff believed that very few incidents are resolved through the use of recorded CCTV video footage. All of the control rooms we studied recorded CCTV video below 5 fps. 10/13 used a real-time recording facility, enabling operators to record an incident in full frame rate (25 fps) when needed to. Based on the comments from police staff visiting these control rooms they were very pleased with the CCTV which recorded incidents at full frame rate, however "when this real-time recording facility was not used, and video was recorded before [at least an hour before] an incident took place – the CCTV video is more or less useless".

(5) Communication difficulties:
(5a) *Noise levels*: During busy periods, the volume of radio and phone calls created a very noisy working atmosphere. At 5/13 control rooms, operators were seen struggling to hear information over the radio because of a high background noise which came from other operators talking mainly when on radio and telephone calls. This was identified as a serious issue for operators, as it significantly reduced their concentration and patience levels when talking to other CCTV users.

(5b) *Too many audio sources*: Operators interacted with a wide range of external departments over the radio and phone throughout their shifts. This meant that operators were required to use several radios and telephones for communication. Unfortunately, these devices were badly positioned in many of the control rooms. The operator shown in Figure 2 said, "…our desks are free from wiring and we have plenty of space for other equipment like monitors…but it's obviously not the right idea cos you know …we can't even tell which phone or radio is going off because they're all laid out in one place".

Figure 2. Badly positioned communication tools: radio and phones placed between two CCTV operators.

Operators at control rooms 2, 5, 7 and 12 also found it difficult to decide which call to respond to first as there was no way of identifying the nature of the call until it was answered. Operators felt that their managers were subscribing too many businesses to the CCTV scheme, and this increased their workload and task complexity.

(5c) *Poor communication between radio users*: CCTV operators and police staff use the NATO phonetic language to describe and clarify names and spellings ("A" for alpha, "B" for beta, etc.), as well as the police identity codes (e.g. IC1 describes a White Caucasian). These codes worked very well – even in the noisiest control rooms. However, not all radio users were familiar with these codes, which made communication with shop radio users very ineffective. An operator at control room 10 reported that, "…some shop managers gave beautiful descriptions, but others were very vague, and they don't tell us where the target is, which is the bit of information we need!"

Shop radio users in central London were often difficult to understand because English was usually not their first language. On a number of occasions, operators were observed asking shop staff to slow down and repeat their messages. Also operators found that "…shop staff don't stay in their jobs particularly long enough to build up a good relationship and rapport with us, so its hard to know who they are". Shop radio users also panicked following an incident and when reporting incidents they spoke too quickly, or gave too much (or too little) information. An operator said that "… shop radio users are incompetent as they shout over the radio and blabber…all we need to know is who they are, the location of the incident and clear information about the incident". Operators reported that they often misunderstood the nature of the incidents which led them to believe it was more serious than it was.

(5d) *Radio tools faulty*: At 6/13 control rooms, communication between operators and other CCTV users was inefficient because faulty radio equipment was in use. Analogue radio was affected by poor weather conditions, and some digital radio systems (called Airwave[4]) did not work properly because of a poor configuration. Encrypted radio systems at one control room interfered with the phone lines.

Discussion

Our field study is the first to assess the effectiveness of CCTV and associated technologies used in CCTV control rooms today. Our research also looked at the human factor issues that affected operator task performance. Our study has found that the design management of CCTV systems need to be carefully considered, and anything that can improve both the effectiveness of CCTV and the operator's job is valuable. A number of usability issues identified from our field study confirm findings from previous research:

1. In a previous CCTV control room study (Gill and Spriggs, 2005; Gill *et al.*, 2005), most control rooms were recording CCTV video at very low frame rates.

[4] Airwave radio is a digital radio communications service that has been designed to meet the needs of the police and other public safety organisations.

2. Luff *et al*. (2000) also found that CCTV cameras used at the London Underground stations produced low quality CCTV video and images because of poor configurations, bad positioning and a lack of maintenance.
3. McCarthy *et al*. (1997) also reported that operators found it difficult to comprehend callers when speaking over the radio to report incidents because callers had strong accents. Poor descriptions also made it difficult for operators to react.

In our study, we also identified that person-to-person communication was ineffective as standard radio protocol was not used. The current study observed the same problems as McCarthy *et al*. (1997) and – to our surprise – we have seen no improvement in this area of work performance in over 10 years. In addition to poor radio communication, we found many other factors that affected communication such as noise, faulty radio tools and the allocation of too many audio channels per operator making it difficult for operators to prioritise calls. Radio and telephone communication is frequent and will always be used in control rooms; however, communication is often overlooked by those who design these systems and control room environments. In the next section, we provide recommendations in review of the major usability issues identified from the field study (see Table 5).

Recommendations

Our findings show a whole wealth of issues that can affect the CCTV operator's performance when working in a security control room environment. We argue that – to make security tasks and operations much more effective – there is a need to improve (1) the design of the technology; (2) the operator's workspace and workflow processes and (3) the surveillance areas outside the control room. In this section, we provide a number of recommendations to improve CCTV effectiveness under each of these improvement areas. These recommendations were formed based on HCI knowledge, discussions with security management and from previous CCTV research and standards.

(1) Design of technology:
(1.1) Automatic fault detection and reporting should be added as a functionality to identify failing cameras. Together with processes and budgets for repair and maintenance (see 2.2), this will ensure that faulty equipment is identified and fixed in good time.

(1.2) Noise within a security environment should be kept to a minimum to avoid task interruption and interference. Radio channels should be distributed among operators, equally and a detachable headset should be used if several radio channels and telephones are in use.

(1.3) Operator's cognitive workload can be reduced if camera lists and maps are integrated into one interactive mapping and database system. Such a tool will increase the operator's effectiveness when responding to events, as they will spend less time and effort searching for cameras/locations and spend more time responding and attending to incidents.

(1.4) To ensure that recorded CCTV video can be used for criminal investigations – VHS tapes should not be re-used more than five times. For digital systems, video should be

recorded to no less than 8 fps (Keval *et al*., 2007) and compressed to no less than 52 Kbps[5] when the system is set up to identify faces unknown to the operator (Keval and Sasse, 2008). The real-time CCTV image on the monitor should be focused so that the size of people within the scene is correct for the observation task(s). This can be achieved by following the Rotakin screen height recommendations provided by the Home Office (Cohen *et al*., 2006). The video resolution of CCTV video should be adequate so that target faces do not fall below the minimum pixel count of 16×16 pixels otherwise identification will be difficult (Bachmann, 1991). As a general rule of thumb, CCTV cameras in high-risk environments should record and distribute video at very little compression, high resolution and at a frame rate of 12 fps or above.

(2) Operator workspace and workflow processes:
(2.1) For the design of a new control room, managers should refer to control room standards for guidance in design (ISO 11064: Ergonomics Design of Control Centres, 2001).

(2.2) Any tools and equipment used for tasks should be tested and maintained every 4–6 months. A process should be in place to flag the presence of redundant equipment and to initiate removal.

(2.3) Tools should also be positioned safely around the operator's workstation and be free from obstruction.

(2.4) To avoid confusion and delays during incident reporting over the radio or telephone, a standard radio protocol should be used, which sets out a rules for communicating information. The protocol should include the use of the NATO phonetic alphabet and police identity codes. Shop staff must be given training and materials when using radios for security support.

(3) Surveillance area:
(3.1) Leaving unused CCTV cameras within the control system will result in the camera lists becoming unnecessarily long and difficult for the operator to manage during reactive surveillance. Cameras in inappropriate positions or with restricted views cameras affect the performance of both reactive and proactive surveillance tasks. Under these circumstances, it is likely that the operator will miss targets/events and may commit errors in identification. To avoid task errors, all the CCTV cameras accessible in the control room should undergo a review every 4–6 months.

(3.2) More consideration needs to be given when maintaining the external surveillance environment. Procedures and lines of communication are important when dealing with these issues. The person responsible for maintaining the camera environment must be

[5] At this video bit rate, this recommendation applies for digital CCTV systems that use MPEG-4 video CODECs and record at the Common Image Format (CIF) video resolution (352 × 288).

established and a budget for maintenance and repairs must be included in the overall CCTV system budget.

(3.3) Illogical camera numbering can reduce the operator's efficiency in searching for targets and locating scenes. All CCTV cameras (including new cameras) should be placed in a geographical order so that operators can logically locate cameras and track targets and vehicles from one camera to another without confusion.

(3.4) As part of operator training, an assessment on camera knowledge, surveillance environment, security procedures and the use of the control room tools and systems should be routinely carried out every 4–6 months.

Conclusions

The environment of a CCTV system undergoes many changes throughout its lifecycle, due to social, technical and environmental developments. We found that the CCTV operator's job is often overlooked by those who own, design and deploy the control room systems. The factors which reduced the effectiveness of CCTV not only affected the operator's performance when carrying out their security tasks, but also other CCTV stakeholders when communicating and responding to incidents.

The technology deployed within a CCTV control room – if configured properly – has tremendous capabilities to support the CCTV operator's tasks. If the technology, however, is poorly designed, the operator will have great difficulty in working out how to use the system which is a waste of investment. Any equipment that is deployed into a CCTV security control room should fulfil a purpose and be an essential part of the system – using technology for the sake of it, never works.

In review of the study findings, we find that it is most striking that none of these problems present a technical challenge, and most do not require much in the way of additional funding. The recommendations for achieving better performance are mundane. But the fact that mundaneness also illustrates the still-widespread inability to understand the technology as a tool to support human activity, and that good performance requires (1) appropriate functionality, (2) design of effective tasks and procedures, and (3) appropriate design of the work environment. We have also seen that (4) it requires that equipment is adequately maintained and (5) adapted to changing tasks and changing environments. Finally, (6) the requirements of stakeholders outside the control need to be considered, and in some cases they need to be trained. There is currently a widespread failure to identify the responsibilities for points 2–6, and to put the required lines of communication and funding in place. Our recommendations are aimed at security practitioners and designers to improve the effectiveness of CCTV for control rooms.

Acknowledgements

This research was supported by an EPSRC grant (EP1P50064811). The authors gratefully acknowledge Peter Fry (ex-U.K. Chairman of the CCTV User Group) for

providing the control room contacts. We are very grateful to all of the CCTV control room managers and operators who volunteered in this study. Without the support and assistance of these participants, the study would have not been possible. We also would like to credit the source and copyright of the photographs taken at the control rooms. We thank all reviewers for their constructive comments after reviewing a previous draft of this paper. We would also like to thank the editor Martin Gill for his help in publishing this paper.

References

Bachmann, T. (1991) Identification of Spatially Quantised Tachistoscopic Images of Faces: How Many Pixels Does it Take to Carry Identity? *European Journal of Cognitive Psychology*. Vol. 3, pp 87–107.

Bentley, R., Hughes, J., Randall, D., Rodden, T., Sawyer, P., Shapiro, D. and Somerville, I. (1992) Ethnographically-Informed Systems Design for Air Traffic Control. In *Proceedings of the 1992 ACM Conference on Computer-Supported Cooperative Work*. New York, NY: ACM Press, pp 123–129.

Beyer, H. and Holtzblatt, K. (1998) *Contextual Design: Defining Customer-Centered Systems*. San Francisco: Morgan Kaufmann.

Blandford, A. and Furniss, D. (2006) DiCoT: A Methodology for Applying Distributed Cognition to the Design of Team Working Systems. In Gilroy, S. and Harrison, M. (eds) *Proceedings of DSVIS 2005*. Lecture Notes in Computer Science, Vol. 3941 New York: Springer, pp 26–38.

BS EN ISO 11064 (2001) Ergonomic Design of Control Centres, Part 1: Principles for the Design of Control Centres.

Cohen, N., Gatusso, J. and MacLennan-Brown, K. (2006) *CCTV Operational Requirements Manual – Is your CCTV System Fit for Purpose?* Vers 4, Home Office Scientific Development Branch (HOSDB) Publication, 55/06.

Gill, M. and Spriggs, A. (2005) *Assessing the Impact of CCTV*. Home Office Research Study 292, Home Office Research, Development and Statistics Directorate, February 2005.

Gill, M., Spriggs, A., Allen, J., Jessiman, P., Swain, D., Hemming, M., Kara, D. and Little, R. (2005) *Control Room Operation: Findings from Control Room Observations*. Home Office Scientific Development Branch Publication, 17/05.

Johnson, P. (1993) *Human–Computer Interaction: Psychology, Task Analysis and Software Engineering*. New York: McGraw-Hill.

Keval, H. and Sasse, M.A. (2006) Man or Gorilla? Performance Issues with CCTV Technology in Security Control Rooms. 16th World Congress on Ergonomics Conference. In *Proceedings of International Ergonomics Association*, Maastricht, the Netherlands.

Keval, H. and Sasse, M.A. (2008) Can We ID from CCTV: Image Quality in Digital CCTV and Face Identification Performance. In *Proceedings of SPIE Symposium on SPIE Defense and Security Symposium*, Vol. 6982: Identification and Feature Detection I, SPIE Defense and Security Symposium, Orlando, U.S.A.

Keval, H., Gatusso, J. and Maclennan, K.B. (2007) Did You See What Happened? A Study On Video Frame Rates for Detecting Events from CCTV Video. A poster presented at the International Crime Science Conference, London.

Luff, P., Heath, C. and Jirotka, M. (2000) Surveying the Scene: Technologies for Everyday Awareness and Monitoring in Control Rooms. *Interacting with Computers*. Vol. 13, pp 193–228.

McCarthy, J.C., Wright, P.C., Healey, P., Dearden, A. and Harrison, M.D. (1997) Locating the Scene: The Particular and the General in Contexts for Ambulance Control. In *Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work: The Integration Challenge* (Phoenix, Arizona, USA, November 16–19). New York, NY: ACM Press, pp 101–110.

Norros, L. and Nuttinen, M. (2005) Performance-Based Usability Evaluation of a Safety Information and Alarm System. *International Journal of Human-Computer Studies*. Vol. 63, pp 328–361.

Twidale, M., Randall, D. and Bentley, R. (1994) Situated Evaluation for Cooperative Systems. In *Proceedings of the Conference on Computer-Supported Cooperative Work (CSCW 94')*. New York, Chapel Hill, NY: ACM Press, pp 441–452.

Appendix

See Table A1.

Table A1 Observation checklist used for the observations at the CCTV control rooms

Operator tasks in context
- 1.1 What hours do operators work?
- 1.2 What tasks do operators perform?
- 1.3 How frequently are these tasks carried (day/night/weekend)
- 1.4 Is the operator's workstation suitable for their tasks?

Artefacts
- 2.1 Is the operator able to communicate effectively with other staff?
- 2.2 What systems are used to perform the tasks?
- 2.3 Are the video signal from street cameras reliable for display?
- 2.4 Is the operator able to communicate effectively using their tools?

Situation awareness – system issues
- 3.1 Is the number of cameras manageable for their tasks?
- 3.2 What tools supports the operator's situation awareness?
- 3.3 Were the information displays well located for the operator to react?
- 3.4 Were there too many displays per operator to search or view?
- 3.5 Were operators able to view the entire camera scene?
- 3.6 Were the camera controls easy to use and usable?
- 3.7 Could the operator access equipment and information when needed?

Processing of CCTV video footage
- 4.1 Could the operator retrieve and make copies of CCTV video
- 4.2 Was the CCTV video usable for investigating crime?
- 4.3 Was the operator able to change tapes using the video recorder? (applicable where analogue CCTV systems are in use)