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Mobile technology for crime scene examination

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Abstract

In this paper, the concept of distributed cognition is used to inform the design, development and trialling of technologies to support Crime Scene Examination is reported. A user trial, with trainee Crime Scene Examiners, was conducted to compare the ways in which evidence search and recovery could be combined with the production of a crime scene report (that must be written at the scene). Participants completed the crime scene report using either the conventional paper form, an electronic form on a tablet computer (to represent the current trend in digitisation of crime scene reports), or a wearable computer (with speech input). While both computer conditions (tablet and wearable) led to faster performance, when compared with the paper condition, there was no difference in content or quality of the reports produced in any of the three conditions; thus, the computer conditions produced acceptable reports in much faster time when compared to conventional practice. Furthermore, activity sampling analysis showed that participants found it much easier to integrate the wearable computer (than either paper forms or tablet computer) into their search and recovery activity.

Keywords: Wearable computers; Tablet computers; Evidence management; Crime scene examination; Distributed cognition; Annotated images

1. Introduction

This paper describes the development of mobile and wearable computers that can be interacted with whilst simultaneously performing tasks associated with Crime Scene Examination (CSE). The procedures governing CSE require that the recording of scene details and logging of evidence should be contemporaneous with the recovery of that evidence (Jamieson, 2004; Hobbs, 1988). In UK there are important differences between the roles of investigators at a crime scene, e.g., search could involve physical destruction of the scene in order to recover items that might be hidden; examination involves the 'harvesting' of material that could be developed and used as evidence (without necessarily causing disruption to the scene); analysis is often performed by forensic practitioners (although, increasingly, there is a potential for analysis to be performed at the same time that it is recovered, e.g., digital fingermark analysis or footwear analysis, or 'lab-on-a-chip' DNA analysis). The primary activities we consider (examine, recover, report) require a Crime Scene Examiner to carry out different tasks on different objects, shifting attention as the activities progress (see Fig. 1). From our notion of CSE as a form of distributed cognition (Baber et al., 2006), we argue that maintaining a task flow on examination of the scene, with pauses for recovery and minimal interruption for recording could be the most effective means of operating. The foreground task for the user would be to examine the scene, and the background task would be to record this information. A wearable system ought to push the recording tasks into the background so as to allow examination of the scene and recovery of evidence to be foregrounded. Further, concurrent recording could support offloading, i.e., the process by which some part of cognitive activity is transferred from

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Fig. 1. Inspecting a crime scene.

the individual to an external artefact or representation. For example, a sketch or image of a scene provides both a record of physical space and the objects it contains, and also a representation that can be manipulated and annotated.

1.1. Distributed cognition

Whereas the distributed cognition literature emphasises that objects can be considered as 'resources' that support particular forms of action (Flor and Hutchins, 1991; Hutchins, 1995; Hollan et al., 2002; Nemeth, 2003; Nygren et al., 1992; Perry, 2003; Seagull et al., 2003), we propose that crime scene examination involves an intermediary step of *recognising* objects as possible resources (Baber et al., 2006). In other words, the definition of an object as a *resource-for-action* requires recognition of its potential as evidence. For this paper, the activity of the CSE has been defined as *examine, recover, report*. For example, dusting a surface to reveal prints is an act of examination (i.e., the surface could reveal more prints when dusted) and followed by an act of recovery (i.e., in order to 'lift' the print the surface needs to be prepared). So, we can assume that the experienced CSE will be able to interleave activities associated with examination and recovery. At present, there is little scope for interleaving reporting with these activities. This has two consequences. First, the requirement for 'contemporaneous notes' could mean that the reporting is performed while the CSE is in the vicinity of the scene (e.g., in their van outside or in another room) rather than when the evidence is being recovered. This makes practical sense, particularly if the scene is small, or there is other forensic activity underway, or the scene is messy. Second, as implied by the first, the act of reporting is seen as something to be done *after* examination and recovery.

Observations in the field and training environments suggest that there are 'natural' breaks in examination when reporting can be performed, e.g., once an item has been lifted and bagged, exhibit labels can be written and part of the report completed. The need for labelling of exhibits and writing of reports relates to the manner in which the exhibits become passed to other agents within the criminal investigation system. Thus, while the crime scene itself could be a resource-for-action for the CSE, the exhibits becomes resources-for-action for forensic scientists, the reports become resource-for-action for crime scene managers, and the combination of reports from the CSE and the forensic scientists (together with the exhibits) become resources-for-action for investigating officers, the Crown Prosecution Service, barristers, etc.

1.2. Designing for distributed cognition

One way of representing the way in which resources-for-action change over the course of the CSE process is to use Wright et al.'s (1996, 2000) 'resource model' (see Table 1).

This 'resource model' aligns resource types with interaction strategies (we have added an additional column to suggest which agents might use these resources and strategies). The resource type is assumed to be a representation of an *abstract information structure*, which could include the goals of the person; the plans being put into effect; the possibilities that objects have for performing actions; the history of previous actions performed by the person or with the objects; the state of the objects; the perceived action–effect relationship of the state of the objects. Each abstract information structure can be represented in a variety of ways, e.g., written or graphical information, the state of objects, the mental model held by the person, etc. The interaction strategies cover particular forms of activity, such as plan construction or plan following, goal matching, etc. Table 1 relates focus of attention of the different agents to the abstract information structures proposed by Wright et al. (1996, 2000).

There are several points to note from Table 1. First, the main focus for the CSE relates to activities associated with the examination of the scene and application of appropriate recovery techniques. From this point of view, the act of reporting is incidental to the goals associated with these foci. Second, the 'history' for the CSE goals relies heavily on the experience of the specific CSE. Smith et al. (2008) suggest that there is little support for sharing information (except for discussions with colleagues either over the radio or in the office). Thus, some means of providing access to 'history' might be useful. Third, the agent column provides a hypothetical chain of agents who may have different interpretations of both focus and goal, e.g., for 'Sample', the goals relate to collecting a sample from the scene; for the CSE this could suggest following procedures correctly to produce a usable sample; for the Crime Scene Manager

Table 1
Relating focus of attention to abstract information structures.

Focus	State	Goal	History	Plan	Possibility	Agent
Environment	Visual inspection	Retrieve objects/evidence	Recall similar scene	Follow Procedure	Objects and surfaces hold evidence	CSE; Investigating officer; Forensic scientist
Surface	Visual inspection or chemical treatment	Examine scene, perform analysis, make recording	Recall likely surfaces to check	Apply technique	Surfaces hold fingerprints, DNA, fibres etc.	CSE; Investigating officer; Forensic scientist
Object	Visual inspection	Examine scene, recover objects, make recording	Recall likely objects	Collect and record	Contain evidence or serve as evidence	CSE; Investigating officer; Forensic scientist
Sample	Chemical treatment	Examine scene, recover samples, make recording	Database of samples	Analyse and record	Evidence can be obtained from sample	CSE; Crime scene manager; Forensic scientist;
Results	Results produced by analysis	Results in the form of graphs and numbers	Database of results	Record and interpret	Results can be interpreted probabilistically	Forensic scientist
Individual	Identified by specific features	Match results to features	Database of features	Compare	Match can be interpreted probabilistically	Investigating officer; Forensic scientist
Report	Collation of material	Produce coherent case	Updating of collection	Compile results, etc.	A case can be made on the basis of the evidence	Investigating officer; CPS; Barrister; Court

this could suggest the number of times a particular type of sample is collected (e.g., there might be pressure from the Home Office to increase collection of DNA from scenes); for the Forensic Scientist type, state and quantity of the sample could suggest the appropriate tests to apply. This can be described as the following requirements:

Object-as-evidence—the recording of information associated with an item of evidence, e.g., in the form of labels, logs and reports;
Context-of-retrieval—the recording of information relating to the location of the evidence in the crime scene and general information about the scene;
Digital record—the production of a digital record that can be stored and disseminated;
Support for collaboration—ensuring that information can be transferred between different computer systems. It might also mean the possibility of supporting discussion between individuals at the scene and somewhere else (perhaps in a laboratory or in the headquarters);
Tracking of evidence is essential to recording who has access to the evidence and what actions they have performed on it. Thus, a challenge for crime scene examination is the tracking of evidence and statements;
The technology should cause *no interference to current patterns of work* and activity; *Issues of contamination* mean that it is necessary to make sure that any equipment taken into a crime scene has not been previously exposed to other scenes;
Content-reconfiguration is essential to analysis: 'raw' materials need to be processed in order to make them amenable to specific tests, and the results of the tests need to be compared with information held in databases in order to produce a confident match with a given individual or artefact.

1.3. Digitising CSE

'Digitisation' has a fundamental role in crime scene examination (Science and Technology Committee, 2005; Flint, 2004; Home Office, 2004; Horner, 2004; Chan, 2003, 2001; Skills Foresight, 2004). While digitisation can take many forms (from the use of digital photography to capture finger or footwear marks to the 'lab-on-a-chip'), our concern is with the digitisation of reporting. There are many ways of converting a paper form into a computer-readable format, e.g., paper forms can be scanned into a database at a later date, or 'digital pens' can be used to complete the paper form, or a version of the form can be completed on a laptop or tablet computer. Each of these options has, to our knowledge, been trialled in different guises throughout UK Police Forces (and is likely to have been considered in other countries).

There is currently much interest in the development and deployment of evidence management systems that can support the tracking of evidence throughout the process. The key issues relate to providing clear and unambiguous identification of evidence, together with a convenient means of tracking this evidence, e.g., in terms of who handles the evidence, who processes it and how it is processed. At present, there are several commercially available evidence management systems in the UK (although more are being developed and launched). The Single Evidential Tracking System[1] (SETS) has been used by Hertfordshire Constabulary since March 2003.

[1] www.compucorp.co.uk/sets

Table 2
Comparing commercial products with design concept.

Requirements	Commercial products	Design concepts
Object-as-evidence	Assign unique ID number to each item; LOCARD uses bar-code stamped bags	Rewritable RFID to hold ID and basic data
Context-of-retrieval	Record scene of crime details in formal report	Time, location, person, etc. recorded automatically on retrieval
Digital record	Unique ID allows association with new information	Unique ID allows association with new information
Support for collaboration		Wireless Local Area Network connection supports up- down-load of information
Tracking of evidence	Manual signature and hand-over; use of unique ID to check integrity	Manual signature and hand-over; use of RFID to record who handles evidence and when
No interference to current patterns of work	Pause in recovery process to type in new information	Speak in new information while recovering evidence
Reduce contamination	Use laptop away from crime scene	Automatic data collection in protected case
Content reconfiguration	Unique ID allows association with new information	Unique ID allows association with new information

The system, running on laptops, can be used at the crime scene and supports recording of Scene of Crime details, Modus Operandi, offences, found exhibits, and Forensic Science Service submissions. Anite's SOCRATES[2] system is a suite of evidence tracking and management systems that not only record information from the crime scene and tracks evidence, but also manages the workflow for Scene of Crime, Photographic, Fingerprint, and Submissions. LOCARD[3] is billed as an automated evidence tracking system. Evidence is placed in bags that have been bar-coded. A barcode reader (interfaced with a laptop computer) is then used to read in the bag's ID so that all future reference to a particular item of evidence can be linked to this ID.

Each approach still requires the clerical act of recording information to be separate from the acts or examination and recovery. In other words, the CSE will examine the scene and then stop to make notes, or will recover an item and then write notes. This implies that some interruption of the CSE process occurs with the need to report (and as more organisations have access to such data, there is an increasing burden on CSEs to produce more detailed reports). Consequently, our intention has been to develop technology that allows the inter-leaving of examination, recovery and clerical tasks. Thus, whilst it is relatively easy to conceive of ways in which information can be collected and digitised, there remains a need to maintain focus on the actual work of the crime scene investigator.

Our point of departure is to consider the way in which the activity of reporting can be made both digital and contemporaneous with the acts of examination and recovery. To this end, we would like to have sensors on the person to collect data on their interaction with the environment and objects, hands-free interaction with the computer and image capture that requires minimal intervention. Table 2 shows how these ideas might be realised and relates them to commercial products.

[2]www.aniteps.com/products/evidence_management.asp
[3]www.locard.co.uk/index.html

Table 2 suggests a key difference between our concepts and commercial products lies in the ability to support reporting while recovering evidence. An initial user trial, reported in Baber et al. (2005), demonstrated a statistically significant performance advantage in reporting the recovery of items using a computer prototype, in comparison with the completion of paper labels and logs. This implied that, while the prototype required a degree of manual interaction with the system, e.g., in terms of aligning the camera and pressing mouse buttons, the paper-based version required participants to continually switch between holding an item and using the pen to make notes. On the basis of the discussion in Section 1, this need to switch attention between searching and reporting could interrupt the flow of the search process. At the very least this has time implications, but more subtly it could result in an interruption to the train of thought that the examiner is following. As mentioned previously, this might be one reason why CSEs tend to complete the report writing during 'breaks' in the search, e.g., when an item has been recovered, bagged and labelled.

2. User trial

The studies were conducted in purpose-built 'crime houses', used as part of the training environment of Teesside University. Each room in the 'crime house' (a former student residence) can be set up to represent different types of room, e.g., small business, kitchen, bedsit, living room etc., and the scenes are dressed by experienced tutors to provide a realistic and convincing scene of a specific crime. In this study, the investigation involved a report of a burglary in a bedroom, and a variety of potential evidence (from finger and footwear marks, to damaged items) was used to dress the scene. Conducting the user trials in the crime houses meant that the studies would be performed in the same environment for all participants, and that we had the opportunity to film the participants and the electronic conditions recorded every interaction with the interface, whether recording or not.

This allowed us to observe exactly how the participants were interacting with the devices.

2.1. Equipment

The application is written in Windows Visual Basic.Net, using the Microsoft Speech Recognition Engine, and runs on either a Samsung Q1 tablet computer with pen interface, or the χ^3 (Chi-three) wearable computer developed at The University of Birmingham (Cross et al., 2003; Bristow et al., 2004). The χ^3 uses a PC104 embedded PC board, with on-board LAN and four USB ports. The main unit is a 533 MHz Pentium class chipset. A Micro-Optical head-mounted display is used (with its own power source and data converter).

In both the tablet and the χ^3 the USB ports are used by a combined barcode reader and RFID reader (purpose-built for this prototype), VGA web-cam, USB microphone and headset. When an image is captured with the web-cam, or a barcode or RFID tag is read from an evidence bag, or a menu item selected (see below) the user is prompted to provide a description of the item and its location.

The data contained on a 'Scene of Crime Report' lend themselves to a computerised system (see Fig. 2). For example, in the Police Force that we were primarily working with, a system of codes is used to identify certain aspects of the crime scene, which are usually obtained from a separate sheet (see Table 3). These codes support indexing, cross-referencing and searching in databases. A short "MO" (50 word *Modus Operandi*) is produced at the top of the form. Artefacts that are recovered as evidence are recorded on the sheet in note form, which may later be added to with forensic results, photographs, etc. Thus, the MO is a human-readable 'summary' of the codes entered into the crime scene report.

Fortunately the form and its codes mean that the 'language' used to describe a scene is quite limited. This, in turn, means that the report could be made up almost entirely by selecting the relevant codes, and assigning photographs of recovered items to well-defined categories (see Fig. 3). We 'build' the MO automatically based on the selections, and fill in other items such as time of day, location, etc. automatically (Fig. 6), e.g., the user says [Scene Details] then [Property] then speak each item that was stolen from the scene such as [Cash].

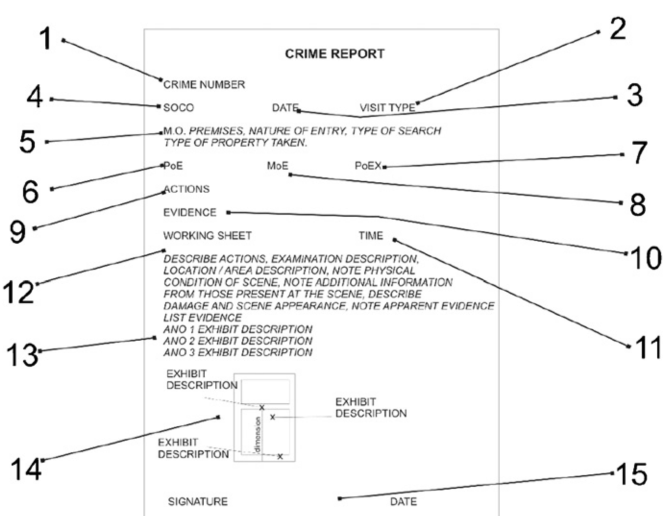

Fig. 2. Crime scene report.

Table 3
Detailed description of content of crime scene report.

No.	Information captured
1	A unique number is assigned to each crime that is reported. This is used to relate different reports to the same crime.
2	The type of visit, e.g., whether there is a 'search' or 'examination'.
3	The date is recorded in all crime reports
4	A unique identification number is assigned to each SCE.
5	The M.O. is the *modus operandi* and is a description of the scene including likely nature of entry, the type of criminal activity, any property taken or personal injury.
6	The POE is the point of entry, e.g., front door, kitchen window etc.
7	PoEX is the point of exit (see 6).
8	MOE this is the method of entry, e.g., smashed, forced, kicked-in etc.
9	Actions that the criminal performed.
10	The nature of evidence recovered. A full listing is provided in 13.
11	The time of the examination is recorded.
12	The working sheet is the CSE's notes and observations on the scene.
13	A detailed list of all items recovered, containing. Each item should have its own unique identifier, e.g., the CSE initials, date, and the item number, together with a short description of the item.
14	The scene is by sketching and diagrams.
15	The form is signed and dated.

In order to support comparison across platforms, we required a user interface that could be run from either the 'buttons' on a tablet PC or through speech on the wearable computer. We used a hierarchical menu organisation. This is defined in an object-orientated manner through Menu, Submenu and then Selection at the terminus of the tree. Each Menu or Submenu contains up to 10 options, and each option can be selected, with a pen tap, a mouse click or by speaking its name. In this way the user can see that only those items on the top or bottom row are valid options from the current state. The user can toggle an option by repeating its name or tapping its label on the tablet screen. The options are displayed on screen (or head-mounted display) to provide a prompt for the user. As the speech recogniser is only listening for, at most, ten different words the accuracy is typically good, i.e., in the region of 96%+ in the environments under test.

Having image capture aligned with evidence recovery means that the CSE is able to photograph items *in situ* and report any interesting aspects of the physical appearance of the scene. If people pass images from the field to a command post, then there could be a need to label items of particular interest or have some means of categorizing incoming images. In other work, we have shown how it is possible to annotate digital images with sketches

Fig. 3. M.O. produced by computer.

(Cross et al., 2003), or through the use of sensors on the image-capture device (Cross et al., 2005; Baber et al., submitted).

When data input is complete, the data structure is then serialised into an XML document. For the user trials, each new participant creates a new record, which they build as they investigate the crime scene. The photographs are stored in the same folder as the data, and are referenced in the record. Later the record can be called up in an explorer-type browser. The record includes a complete timeline audit of all the interactions and selections made by the user. From this it is possible to build a timeline of exactly what the user did and in what order. This may be used later in order to associate findings from multiple investigators over the course of time.

In summary, the paper form currently used by Scene of Crime Officers has details of the crime logged as a series of codes. In our system, we used these codes as menu options, and the system automatically combines these into the MO. Our trials were arranged so that the language was sufficient to cover the crime scene, and we used real codes. The MO acts like an executive summary of the scene findings, and thus is suited to being sent as a text message, for example, to the coordinator of multiple scenes.

3. Method

3.1. Participants

We conducted a user trial involving 15 students from a third-year Crime Scene Science course. This provides a reasonable control of experience of CSE practice. The students had received training in evidence search, recovery and analysis, as well as reporting and presentation of evidence. Many of the students from the courses go on to work with UK Police Forces or Forensic agencies. Thus, despite being students rather than practitioners, we feel that their skill set is well-suited to our investigation.

3.2. Procedure

To directly compare the paper and computer methods for data capturing, we divided the students into three groups of five. Each group was set the task of recording a 'dressed' crime scene involving a break-in via a window, with evidence such as fibres and blood left at the scene. In this data capturing trial, we identified a number of items that should have been recorded, for each participant we logged a miss or a hit for each item.

In order to control for familiarity, the 'paper' condition was based on the layout of the forms shown in Fig. 3 (obviously the buttons were removed). This represents a marginally different appearance from the forms with which the students were familiar. Comments from the participants in this condition, and tutors at the University, confirm that the report format had a 'look and feel' that was similar to the forms that they were used to. A further point to note is that, in the UK at least, different Police Forces tend to have their own unique variations on the Crime Scene reporting form (together with some variation in the codes used on these forms). This would mean that a 'different' format would not be unusual. Each student was given a brief explanation of the reporting process in each condition, and asked to complete an example through a 'desk-top' simulation prior to commencing on the study. This 'training' took between 5 and 10 min per participant, with training being defined by the participant being able to demonstrate the use of the equipment to the experimenters. Fig. 4 shows participants in the computer conditions examining the scene and recording their findings.

Participants were given an initial account of the crime by one of the experimenters, playing the role of the householder. This account emphasised that the householder had returned home to find the place in disarray and items missing. The CSE was asked to examine the scene and complete a report which would include (as standard practice requires) a description of the presumed *Modus Operandi* of the criminal, and a record of any items recovered as evidence. They were free to search the scene for as long as they felt appropriate and the task ended when they submitted their report to the experimenters. This meant that participants in the paper condition would hand over their handwritten forms, and participants in the computer conditions would print off the completed form. We had discussed whether to ask participants in the paper

Fig. 4. Participants in computer conditions.

condition to type their report into a computer so as to produce a similar form to the computer conditions (and also to ensure a digital record from all conditions). However, it was felt that this would impose an additional task of these participants, which is not normally performed at the crime scene and so not included in this study. Obviously, any time savings observed when using the computer conditions would be amplified by consideration of the additional time it would take for the CSE to type information from their paper notes into a computer, which could easily take CSEs 15–20 min for each scene at the end of their shift (assuming around 6 scenes per shift, this could easily add almost 2 h to their work, so that scene digitisation can be very attractive).

3.3. Metrics

The three measures used in this study were time to complete the search of the scene; the type of information collected; and an activity analysis of how actions were performed. We were interested in the measurement of time to complete the search (from entry to completing the report) because there is growing pressure on the Crime Scene Examiner to complete scenes efficiently in order to allow several scenes to be completed in a shift. This would mean that any performance advantage would be of interest to the procurement of digital technology to support the CSE. The Metropolitan Police Force have been exploring the possibility of a '30 min' timeframe from evidence recovery to analysis to suspect identification to suspect apprehension. Within such a limited timeframe, any savings in time during the recovery and reporting stage of the investigation could prove very useful.

The second metric relates to the content of the reports. We require an output that can be comparable to standard reports and that can be used for the variety of purposes suggested in Table 1. We were interested in the type of information collected because there is a possibility that the 'free-form' entry on paper might lead to more varied information than the 'fixed' entry from the menus in the computer conditions, or the computer conditions might not include all aspects of the crime being examined.

The third metric relates to the impact of the technology on activity. We consider the manner in which the tasks are performed and how well participants would be able to interleave reporting with the other activity.

4. Results

4.1. Transaction time

Fig. 5 shows that, on average, the Electronic methods were faster than the paper method, with both the Wearable and the Tablet PC condition averaging about 22 min, with the paper condition averaging about 41 min. If we examine the data in more depth we found that there is a statistical main effect of media [$F(2,14) = 8.84$, $p < 0.005$]. Post-hoc, pair-wise comparison using *t*-tests shows significant differences between the paper and the tablet ($t(4) = 4.819$, $p < 0.01$) and the paper and the wearable ($t(4)) = 4.859$, $p < 0.01$) but no significant difference between wearable and tablet in terms of overall time ($t(4) = 0.21$ ns). Participants in the paper condition felt that they were performing at a 'normal' speed, in that the examination of a domestic burglary would typically take around $\frac{3}{4}$ of an hour to 1 h (see Smith et al., 2008). This suggests that the performance times for this study were ecologically valid, and implies that any observed reduction would credibly apply to operational settings.

4.2. Recorded information

Table 4 suggests that computer conditions were able to record all the items. This shows that a relatively complex and complete record including the annotated pictures, description, etc. can be entered using a predominantly hands-free design. In fact, the hands were only used to operate a mute switch and to better frame the photographs. We used the mute switch much like a push-to-talk switch, thus preventing the system responding to spurious words. During discussion with participants following the study, we asked whether they felt unduly constrained by the menu items in the computer conditions and most felt that the items available provided a good level of choice for phrases to describe the MO. One participant commented that the

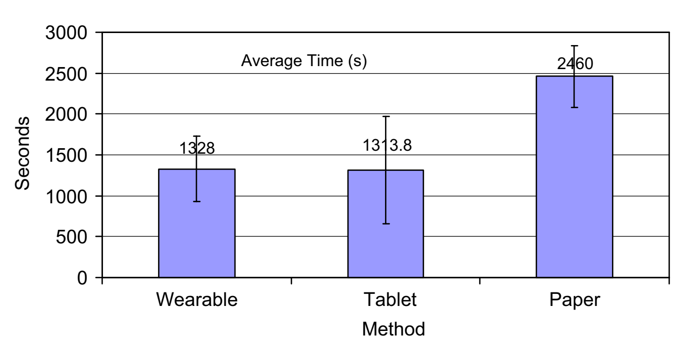

Fig. 5. Transaction times for study two.

use of an electronic form would reduce the number of items that would need to be considered because it would be possible to limit the choices as one more entered information, e.g., once a 'Window' had been identified as a Point of Entry, then the number of options by which a window could be used could be limited to forced, smashed, opened.

Supporting Concurrent Activity: In terms of performance time and information capture, the results suggest that the electronic conditions are faster than the paper condition yet still contain the data required. To find out why this should be, we conducted activity sampling of each participant using the system. The video recording of each participant was analysed by two of the experimenters, independently. At intervals of 20 s, the current activity was classified in terms of the three primary activities, i.e.,

(i) Examine
(ii) Recover
(iii) Report

If more than one activity was occurring at the sampling time, then all current activities were recorded. This provided a timeline showing activities at each 20 s sample period. This information is presented in the following figures.

When the Paper condition is studied, the participant switches between the examination and clerical activity (see Fig. 6). This is typically what one would expect, as they need to pick up the paper and pen in order to make a recording, and in this case some prefer to remove crime scene gloves in order to write.

In the Tablet condition, a similar division of activities can be seen (see Fig. 7). The primary difference is that participants appear to memorise information before committing it to the computer, possibly because they tended to leave the tablet in a 'safe' convenient location whilst they then did manual tasks. This procedure then gets repeated until they are satisfied that the data has been

Table 4
Comparison of report completion across conditions.

Data captured per trial	Pen and paper	Tablet	Wearable
Crime number	4	5	5
SOCO ID	5	5	5
Date	5	5	5
Visit type	4	5	5
MO	5	5	5
PoE	5	5	4
MoE	5	5	4
PoEx	5	5	4
Actions	5	5	4
Evidence	4	5	5
Time	5	5	5
Inclusion sum (%)	52 (95)	55 (100)	51 (93)

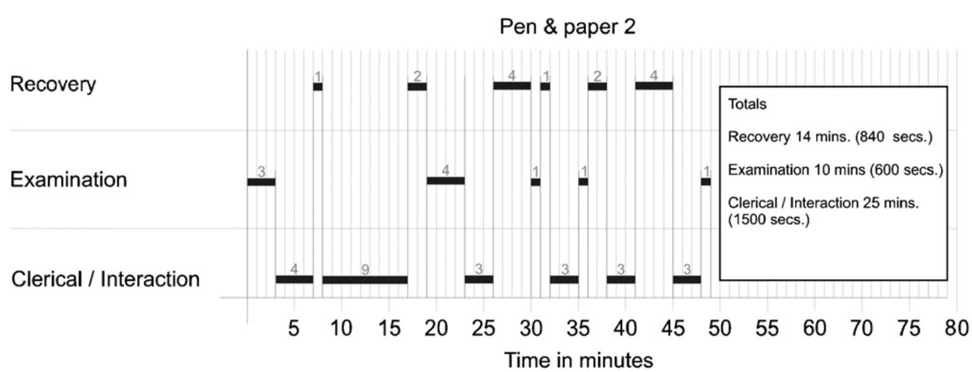

Fig. 6. Activity sampling in paper condition.

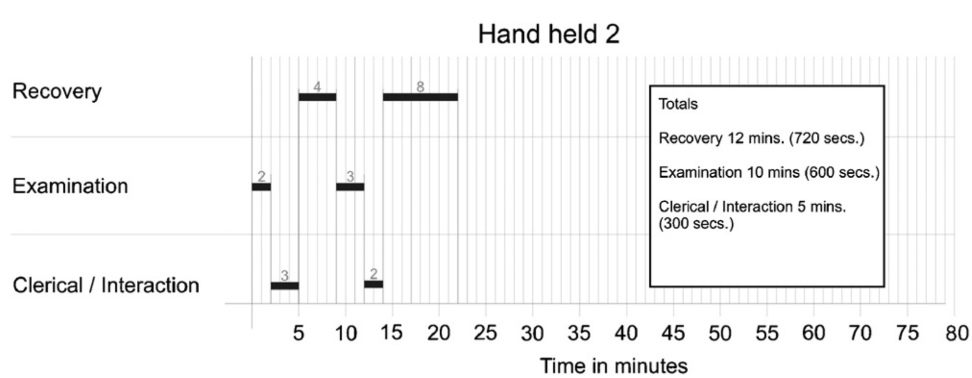

Fig. 7. Activity sampling in tablet PC condition.

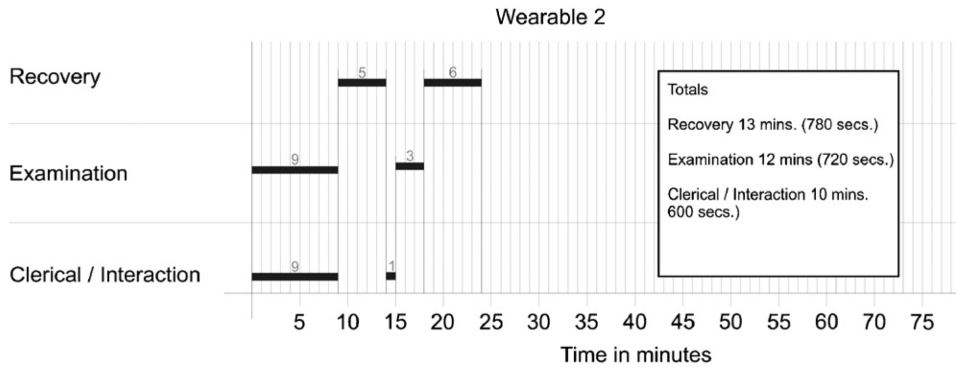

Fig. 8. Activity sampling in wearable computer condition.

recorded satisfactorily. The user interface tended to lead the participants through screens which they then knew the responses to, and this helped to reduce the time required to complete the overall exercise.

When the wearable is used, task concurrency becomes obvious (see Fig. 8). Participants can be seen to be recording in parallel with examination or recovery activities. This suggests that the wearable computer is changing the nature of the work being performed.

5. Conclusions

Overall, the user trial has demonstrated that not only does the paper condition perform significantly more slowly than the computer conditions, but also that the wearable computer condition leads to far better interleaving of tasks than either of the other conditions. The implication is that, even though the tablet PC leads to faster performance than the paper, it is less effective than the wearable because the tablet still involves division of attention across examination, recovery and reporting tasks. Furthermore, it was interesting to note that giving participants the opportunity for relatively ‘free’ entry (albeit constrained by specific codes) and free text description of a *modus operandi*, there was no obvious difference between the text in the reports produced in the different conditions. This implies that, using a constrained vocabulary that is ‘habitable’ to the task at hand (Hone and Baber, 2001) can lead to performance as successful as a free entry.

6. Discussion

6.1. How is CSE ‘distributed’?

The paper suggests that CSE work is distributed in three senses. First, there is the distribution of attention between the activities involved in searching, recovering and reporting. Our prototypes have been designed to allow concurrent performance of reporting with the primary tasks of search and recovery. Second, there is the distribution of cognition between CSE personnel and the scene itself; the manner in which the scene is examined provides hints and cues to what evidence to recover, and interrupting this process (through the need to complete lengthy reports) could disrupt this process. Third, there is the distribution of information between CSE personnel and other people involved in the investigation. By providing real-time digital records of the examination, and allowing shared annotation of these records it is possible to support collaborative working.

6.2. How does use of images change reporting and collaborating?

It is interesting to note that participants in both computer conditions took far more photographs than people in the paper condition made sketches. For instance, in the paper, participants would probably make a single sketch of the scene (usually the window as this was the point of entry) and add some comments, measurements and annotation to this. In the computer conditions, participants took photographs not only of the scene (which they also annotated) but also of objects in the scene. This implies that participants were able to build up a record of their examination through the temporal sequence of these images. While this was not the focus of this study, it does point to an interesting opportunity for further development of recording that it entirely based on sequences of tagged images. This concept is illustrated by Fig. 9.

So far, we have considered ideas of providing images with some meta-data tags, or sketches on images to manage activity. This provides some capability to annotate the image, albeit in a basic manner. However, as Boujout (2003) notes, the practice of annotation is often subordinate to verbal discussion, especially in desktop systems. For example, an annotation is used to point to a feature that the person is talking about, or speech is used to explain the nature of a given annotation. If annotation of images collected at the scene is to be used to support coordination, then a better understanding of the manner in which these practices arise and are used is needed. Boujout (2003) suggests that, over time, the annotations form a

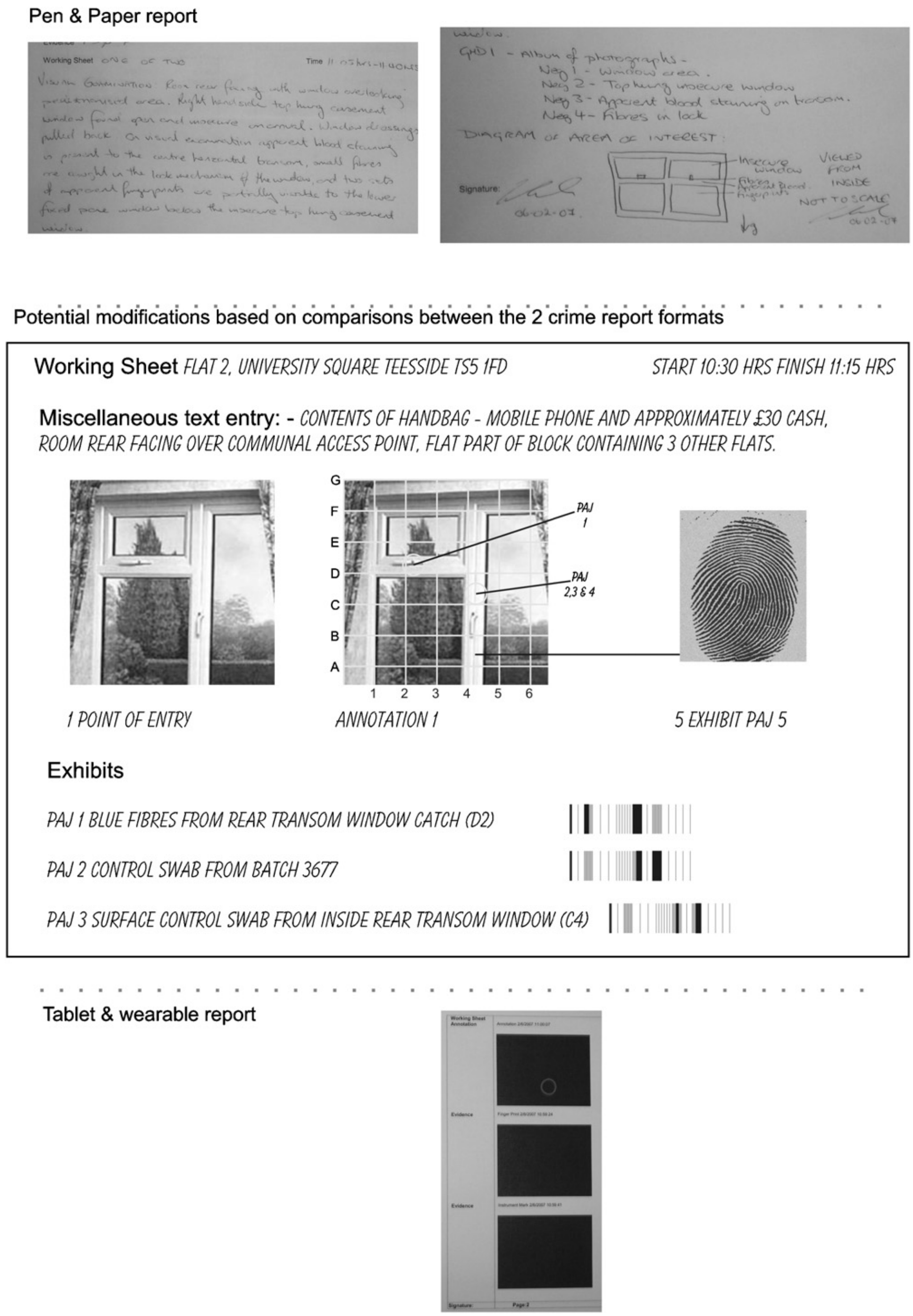

Fig. 9. Compiling a report from images.

'shared repertoire' within a given community of practice. The use of standardized annotations on images could also provide additional support to organisations that use a variety of different languages.

6.3. How does mobile/wearable technology change work?

The main changes that we noticed during our trials were associated with the time and quality of the recording process. In general, using computers sped up the process but did not adversely affect the quality of the recording. A more important finding relates to the manner in which the wearable computer supported concurrent activity. This is interesting in that, while the tablet PC also resulted in faster transaction time, the manner of interaction was similar to the paper process. This implies that the tablet PC helped to speed up the 'clerical' aspects of recording but did not necessarily alter the manner in which activities were performed. The wearable computer, on the other hand, not only led to faster performance but also changed the nature of the work.

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