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# *Supporting Naturalistic Decision Making Through Location-Based Photography: A Study of Simulated Military Reconnaissance*

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Close Target Reconnaissance (CTR) patrols can be characterized by activities that involve naturalistic decision making to develop situation awareness through processes of sense-making. Any technology that is introduced into such activity needs to be sufficiently "invisible" so as not to disrupt or otherwise interfere with the activities of search and interpretation. It is proposed that some technologies, such as imaging devices, can support recognition-primed decision making (RPDM). It is suggested that providing CTR patrols with cameras could supplement existing technologies, such as night vision goggles or binoculars, and provide an opportunity to capture useful intelligence. The concept of location-based photography (in which metadata are collected in parallel with images) provides a means of effectively producing patrol reports in real time. A prototype system is described and trialled comparing conventional practices surrounding note-taking and report writing with the use of location-based photography. The results show little difference in time spent patrolling under the two conditions but significant improvement in reporting under the location-based photography condition. One explanation of these differences relate to the manner in which note taking provides support for sense-making but could interfere with RPDM (through the need to analyze the situation in sufficient detail to make notes), whereas imaging can be performed as part of the RPDM activity. Tagged images change the nature in which the reports are written in that sense-making is performed largely post hoc, which allows flexibility in interpretation and analysis.

## 1. INTRODUCTION

The focus of this paper is on the potential use of location-based photography to support the gathering of intelligence in the field. Current military activity, although it *might* allow patrol members to take photographs, tends to rely on

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memory and brief notes and sketches that can be combined after the patrol during debriefing. There are clear benefits to the use of handwritten notes to support the collection of intelligence during a patrol, that is, it is cheap, flexible and robust. Furthermore, writing notes provides an opportunity to conduct sense-making in situ, such that the act of writing notes becomes a process of interpreting the situation and defining relevant aspects. Finally, the notes and observations made during the patrol then help to structure the final report (indeed, it is likely that knowledge of the content of the final report will shape the nature of the notes that are made and the intelligence collected). Thus, note-taking could be seen as not only the dominant paradigm for intelligence reporting in the military but also the *natural* approach to conducting sense-making. This would mean that any alternative approach would need to offer obvious benefits before it can be seriously considered.

There are two key assumptions underlying the concept presented in this paper: first, that the act of taking a photograph can be mapped onto naturalistic decision making, particularly recognition-primed decision making (RPDM). Thus, it is assumed that rather than taking photographs in a random and haphazard manner, there is a need to conduct purposeful-photography; this implies that the photographer would see something that was of potential interest and take a photograph but would not need to engage in interpretation until later when the photographs would be reviewed. Second, the act of taking a photograph can be seamlessly embedded in ongoing search and inspection (which makes it easier to collect intelligence). A challenge for the development of computer-based systems to support such photography lies in the need to translate from photograph to report; whereas notes made at the scene are in text (and can be easily entered into report forms), photographs have to be reinterpreted to generate text. However, with the advent of location-based photography, it is possible to build text into the metadata for the photograph. Thus, one can capture a photograph together with location (through Global Positioning System [GPS]), direction of shot (through electronic compass), and user-defined tags (through simple menu systems). In this way, the photograph has both visual and textual properties. Appropriate selection of tags means that it is also possible to automatically generate a report through collation of metadata.

This article considers military reconnaissance as a possible application domain for location-based photography and begins with an outline of the activities involved in a specific form of reconnaissance. Although the application domain is military reconnaissance, it is proposed that the arguments and concepts can be adapted to a wide range of other domains in which it is necessary for operators in the field to be able to collect and report information in as unobtrusive a manner as possible. Indeed, the work arose out of previous studies into crime scene investigation (Baber, Smith, Cross, Hunter, & McMaster, 2006; Baber, Smith, Panesar, Yang, & Cross, 2006; Baber et al., 2009). Care has been taken to balance the level of detail necessary for the reader to understand the activity with the need to recognize that military operating procedures and protocols are, in this instance, sensitive. Following this outline, a description of the prototype used in the trials is presented to illustrate the type of activity that could be supported. Finally, a user trial is conducted in which we abstract from the military reconnaissance domain into a sanitized, civilian application to compare the effectiveness of location-based photography with the use of handwritten notes. Although such a "bake-off"

experiment inevitably compares "chalk with cheese," in that the manner in which information is collected differs across conditions, we have tried to maintain a comparable level of performance by focussing on the resulting reports that were produced as a result of the two conditions. In this way, we consider how the final product of a patrol (i.e., a patrol report) is influenced by the use of different approaches to data collection. Close Target Reconnaissance (CTR) patrols are already burdened with kit and might need to carefully consider whether a new product would be welcome. We note that current kit might contain devices to aid vision, such as binoculars or Night Vision Goggles, and to support communications, such as personal radios and mobile telephones, as well equipment for personal survival and protection. However, we would suggest that, if a device that is no bigger than a mobile telephone (which many soldiers carry) could be used for location-based photography, then this might be considered beneficial and could enhance activity (particularly if the device could ultimately generate a first draft of the patrol report).

### *1.1. Perspectives on CTR*

There are many ways in which information is gathered through military reconnaissance: armored reconnaissance squadrons screening forward of a formation's advance, embedded covert human observers, information gathered by remote electronic means, Unmanned Aerial Vehicle reconnaissance are a few examples. A baseline to all these methods (for the British Army) is taught during Phase One infantry training to all British Army personnel: the section-level CTR patrol. As opposed to some of the methods just listed, CTR is available to the infantry commander at the lowest level of command (i.e., section-level) and is often employed after specialist techniques to gain up-to-date information and to fix the enemy in position prior to offensive operations. Thus, one could view CTR as a primary means of developing and enhancing the situation awareness (SA) of the section commander. This means that, unlike specialist sources, which are not always available, CTR patrols have the ability to hold ground for long periods and provide a live feed of enemy information directly to the section commander.

In its broadest sense, reconnaissance is concerned with searching for aspects of the environment that could have a bearing on subsequent actions. Given the likelihood that dismounted reconnaissance, whether performed overtly or covertly, will involve other demands on the person's attention (not least of which would be threat of attack or discovery), then one can see that there is likely to be a significant requirement to be able to rapidly categorize aspects as being relevant or not. Often this rapid categorization could be performed at a level that is difficult to articulate; the UK Army speak of the "atmospherics" of a situation, meaning the feeling or sense of situations that are not "normal." This points to the underlying notions of naturalistic decision making, which Klein (2008) recently articulated as follows:

> People were not generating and comparing option sets. People were using prior experience to rapidly categorize situations. People were relying on some kind of synthesis of their experience—call it a schema or a prototype or a category—to make these judgments. The categories suggested appropriate courses of action. (p. 457)

One approach to conceptualizing naturalistic decision making is as RPDM (Klein, Calderwood, & Cinton-Cirocco, 1986), which posits that people develop schema or "patterns" on the basis of their experiences of a set of related situations. Thus, a person would be able to develop the ability to recognize and extract relevant cues in an environment and use these to define a match between what is happening and what action is required. The notion of RPDM suggests that much of this matching of appropriate action to a situation is performed "intuitively" because the experienced firefighter, police officer, military commander, paramedic, and so on, is able to rapidly assess the situation, recognize the relevant features, and select an action that "fits" (without going through a lengthy and involved process of reviewing courses of action). Of corse, this does not mean that human behavior is simply a matter of conditioning (i.e., in which a particular stimulus always evokes a particular response), but it does suggest that experience provides an opportunity to make shortcuts in decision making under pressure.

The combat effectiveness of the CTRpatrol can be defined in terms of the appropriateness of intelligence acquired during the patrol and the speed at which this intelligence was acquired and disseminated. Considering that appropriate intelligence relates to "ground truth" regarding the enemy and the ability to select a suitable corse of action, this means that the acquisition of this intelligence can be defined as both an increase in the commander's awareness of the situation and a decrease in uncertainty regarding a suitable course of action. It is worth noting that the CTR patrol report is not the only information required for a commander to conduct a successful estimate: Prior intelligence from other sources, experience of engaging this particular enemy, information regarding the terrain, and knowledge of the commander's own assets and abilities are equally important in developing situation awareness. In this article, we take the definition from the UK MoD concept of Network-Enabled Capability as "providing a shared understanding and interpretation of a situation, the intentions of friendly forces, and the potential courses of action amongst all elements in the battlespace" (Dstl / IMD/ SOS/ 500/2, 2003, p. 4). The general approach to Situation Awareness remains indebted to the original formulation of Endsley (1995). She suggested that this involves a three-state process by which the elements and environment of a particular volume of space and time are first perceived, then comprehended, and then future status is projected. The questions considered by the CTR patrol leader during the patrol can be related to the seven questions of the Combat Estimate used in the British Army, for example,

- *Perception.* Where is the enemy; how many; what equipment does the enemy have?
- *Comprehension.* Why are the enemy there; what are they doing?
- *Projection.* What are the enemy's intentions; what are they likely to do if attacked?

In these terms, SA and RPDM could be considered similar concepts; both are concerned with the ways in which people can attend to salient cues in the environment to make a judgement as to what action to perform. However, although RPDM is primarily concerned with explaining how the selection of an action can be made

very quickly through pairing the salient features with previous experience, SA is also concerned with considering broader issues of future state. Even though both notions could be considered in terms of the "snap decisions" made under pressure, one could argue that RPDM is focussed on immediate activity, whereas SA could take a richer view (with it implication that comprehension and projection are considered). Both sets of activity ultimately contribute to the overall goal of sense-making for the ongoing situation.

Sense-making is "a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively" (Klein, Moon, & Hoffman, 2006a). We would view photography as potentially forming part of this process, particularly in terms of capturing aspects of the environment for use in this "connection-forming" activity. "Sense-making is the process of fitting data into a frame and fitting a frame around the data" (Klein, Moon, & Hoffman, 2006b, p. 71), which implies a two-way process of seeking connections between available data, and then seeking to acquire information to support these connections, and using the acquired information to suggest new connections. We have seen how the section commander will rely on a host of information sources to develop an understanding of current operations in terms of situation awareness. One implication of this view is that sense-making is concerned less with seeking a "truth" than with developing and testing plausible explanations of situations and events (Dervin, 1998). The notion of plausibility also implies that sense-making is largely retrospective (based on collected and interpreted information) rather than prospective (although it does require a degree of anticipation in its use of frames) and has a strong potential to be a social activity that is concerned with establishing a "common ground" (Clark, 1996) between individuals. Weick (1995) defined sense-making as a process that could be characterized by seven properties. Although these properties were originally intended for the description of organizational behavior, we feel that they can be translated to this study, as shown next (terms in italics taken from Weick, 1995, p. 17):

1. *Grounded in identity construction*—The actor's behavior is influenced by the role that they assume in the activity. From this, one might further distinguish the act of taking a photograph as being the creation of a "product" (a good photograph) or the management of a "process" (a photograph that captures something happening).
2. *Retrospective*—The sense-making process results in narratives that can be used to justify decisions, actions, and communicated information, for example, how the photographs are not only taken to capture the presence of actors in a particular place but also how these photographs might be used later to develop a narrative of a sequence of events or to provide cues for reflection or subsequent information search.
3. *Enactive of sensible environments*—Actors respond to specific features of the environment because these features draw their attention through their conspicuity, their design, or through the actor's expectations, for example, capturing particular aspects of the location.
4. *Social*—Sense-making is, by definition, a social process that involves the exchange and elaboration of information, for example, in terms of deciding

what level of detail to capture. In this study, the social aspect was related less to the capture of the image and more to the notion that it would be used as the basis for subsequent report writing.

5. *Ongoing*—Sense-making, as a process, is dynamic, for example, in terms of a sequence of photographs taken during the corse of a patrol or series of patrols.
6. *Focused on and by extracted cues*—In addition to being performed in a specific environment, sense-making involves the deliberate extraction of information, for example, whether to capture a bazaar to show how busy it is or whether to capture the behavior of one or two individuals.
7. *Driven by plausibility rather than accuracy*—The goal of sense-making is to achieve an appropriate consensus on the situation, for example, to construct images that can be used as the basis for reporting the patrol.

Situation awareness is not the same as sense-making, that is,

> situation awareness is about the knowledge state that's achieved—either knowledge of current data elements, or inferences drawn from these data, or predictions that can be made using these inferences (Endsley, 1995). In contrast, sense-making is about the process of achieving these kinds of outcomes, the strategies, and the barriers encountered. (Klein et al., 2006, p. 71)

Prior to the patrol, the patrol leader will be provided with orders, which may include intelligence received from other reconnaissance methods, analysis of previous operations, and objectives for intelligence to gather from the patrol. The patrol will produce information that is observed directly and that can be reported in real time. In addition, the patrol will produce a detailed report. Thus, one can summarize this collection process in terms of Perception, Interpretation, and Projection. This is shown in Table 1.

From this discussion, it is proposed that sense-making could be considered as the informed reflection on the situation, whereas RPDM could be considered as the overall "impression" and "feeling" of the situation. To this end, one could argue that note-taking would, by its very nature, accord well with sense-making in that it involves the person in reflecting on the situation in such a way as to be able to articulate facts, features, and concerns. This means that notes made during the patrol would already reflect much of the thinking and awareness of the patrol leader prior to writing the report. On the other hand, photography could be used

**Table 1: Sense-Making and Situation Awareness**

| *Sense-Making* | *Situation Awareness* |
|---|---|
| Grounded in identity construction | |
| Retrospective | Interpretation |
| Enactive of sensible environments | |
| Social | |
| Ongoing | Projection |
| Focused on and by extracted cues | Perception |
| Driven by plausibility rather than accuracy | Interpretation |

to capture the "impression" and "feeling" without explicit commitment to the facts, features, and concerns. This provides a convenient way of setting up the comparison between conventional practice and the use of location-based photography. However, before exploring this further, the next section contains an overview of the CTR patrol.

### *1.2. The Process of the CTR Patrol*

Prior to considering the doctrinal CTR patrol, it is useful to situate the patrol in terms of the wider context of intelligence-led operations. The information in this section is based on *The All Arms Tactical Aide Memoire (Restricted)*, personal experience of military service of one of the authors (CF), and discussion with training staff in Div Land Recce at the Land Warfare Centre, Warminster. This information was synthesized to form Figure 1.

Information gathered by any reconnaissance method feeds an estimate process undertaken by the section commander and his staff, which then lead to consideration of possible courses of action. The quality and accuracy of information gained during reconnaissance has a direct impact on the course of action selected. Tempered against quality is the requirement to act as fast as possible in order that the enemy force does not have time to react effectively. An organized, manouevrist enemy will be engaged in the same Observation, Orientation, Decision, Action (OODA) loop cycle (Boyd, 1995) as the friendly force. For any offensive action to achieve surprize and deception the Commander's OODA loop cycle must be quicker than that of the enemy's. In effect, the commander aims to operate a tempo of military activity faster than his opponent can react, breaking the opponent's cohesion and will to fight. The central boxes in Figure 1 show Boyd's OODA Loop. The boxes outside this loop relate to the typical cycle of military actions placing the CTR patrol in a wider context: The CTR is used to "find and fix" the enemy; the intelligence gathered by the patrol feeds the commander's estimate process; the commander may decide to launch an offensive operation based on the intelligence gathered. After the offence the enemy will need to be observed again by reconnaissance to assess the effect on the enemy of the operation and to assess the enemy's future intent. The lower sequence of boxes show the high-level goals of the CTR patrol. Preliminary actions within this level include the patrol leader receiving his orders together with any intelligence already known and then extracting and issuing his own set of orders to the patrol. Subsequent to the reconnaissance itself, the patrol then writes a formal patrol report, which is submitted to the commander to feed into the estimate process. A useful report is one that not only confirms the information, which can be gained from a serious map and aerial study, but enhances such study.

### *1.3. A CTR Information Chain*

Information gained on the patrol is shared between the patrol members and patrol leader during debrief, between section commander and the patrol leader via the patrol report, and between section and headquarters via section commander

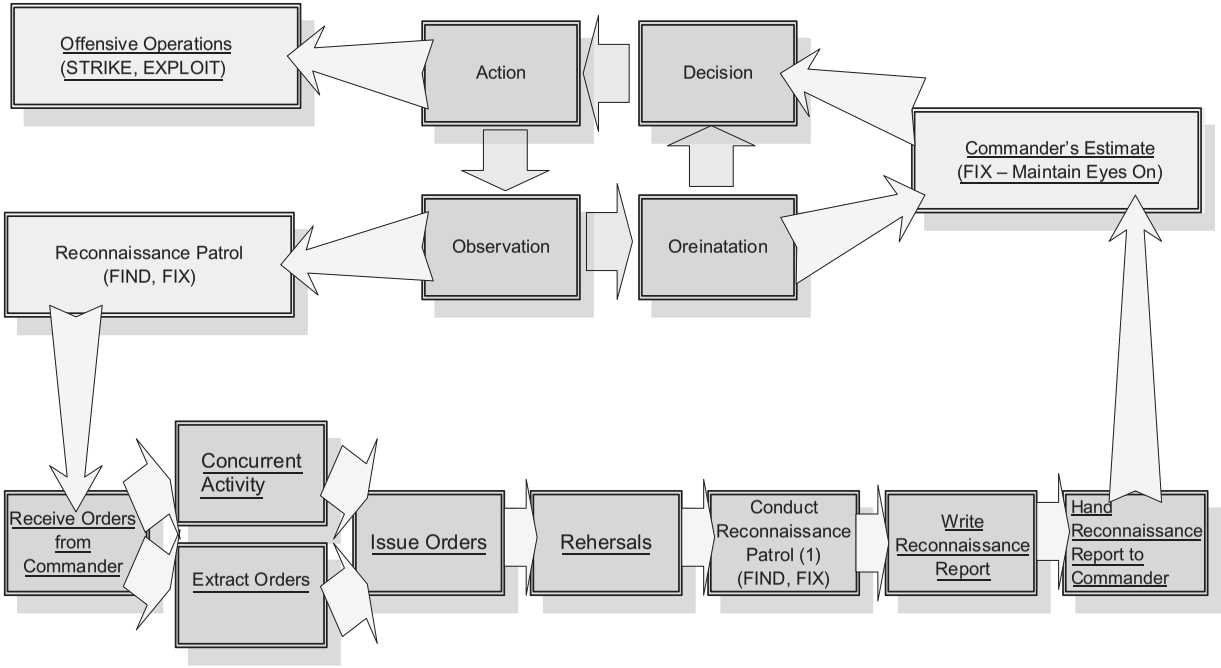


**FIGURE 1** The close target reconnaissance patrol and intelligence-led operations.

reports. The information flow from the section commander to patrol leader prior to the deployment of the patrol will be as follows: The commander will conduct a planning estimate and issue the patrol leader with orders, that is, a set of tasks together with the analysis of all the information that is current available. After the patrol, the patrol leader will present a full summary of the patrol's findings in the form of the patrol report. This report can include sketches and photographs taken during the patrol but is often a textual e-mail sent to brigade with attachments. The flow of information amongst the patrol members, and between the patrol leader and commander, during the patrol can be considered as a for-stage iterative loop. The inside *Rapid Action Cycle* in Figure 2 shows the process where the patrol leader takes the initiative without consultation with the commander in changing the tasks and focus of the patrol. The larger *Deliberate Action Cycle* is similar to the larger operational process of intelligence-led operations however occurs when information is communicated to the commander and the commander then redirects the patrol's tasks. Progression around the loop will increase situational awareness and results in dynamic intelligence-led intelligence gathering during the reconnaissance task.

The generic patrol report describes the complete set of information that the patrol leader presents to the section commander following the patrol. Figure 3 shows the areas of information that form the patrol leader's goals in writing a useful patrol report. The section commander may have a wider understanding of the enemy and may have deployed a number of reconnaissance patrols to investigate a large area of potential enemy positions; he will also have a higher level of his own chain of command's intent. The patrol leader will largely be focused on the enemy target that he has been assigned. Prior to the patrol, the patrol leader will have access to the information contained in the blue boxes on the left side of the figure. This information may include intelligence received from other reconnaissance methods and long-term analysis of the enemy's modus operandi through previous operations. The patrol leader will also have knowledge of his own forces which the commander may be planning to use for subsequent offensive operation. This a priori information will generate the goals (mission and tasks) of the patrol itself. These goals could be simple ones such as confirming the number of enemy already observed during previous reconnaissance or more complicated, such when there is very little previous intelligence available. The gray areas show that information which is observed directly on the ground by the patrol relating to the enemy and the terrain. The green areas show that information relating to force capability, in conjunction with the terrain this is used to deduce low level tactics such as the fields of view of a positioned enemy machine gun for example. The next stage of analysis is the product of a consideration of enemy force asset disposition to assess the enemy's intentions, shown by the red area. Once these intentions are known, subsequent offensive action can be planned; potential force locations during offensive action can be considered—the yellow boxes—and finally a number of courses of action can be generated for an assault and presented to the commander. The patrol leader will cycle through these stages during the patrol. As new information is received during the patrol he will reassess all information available altering reconnaissance tasks to best achieve the commander's intent. The patrol leader's cognitive process in forming the reconnaissance report

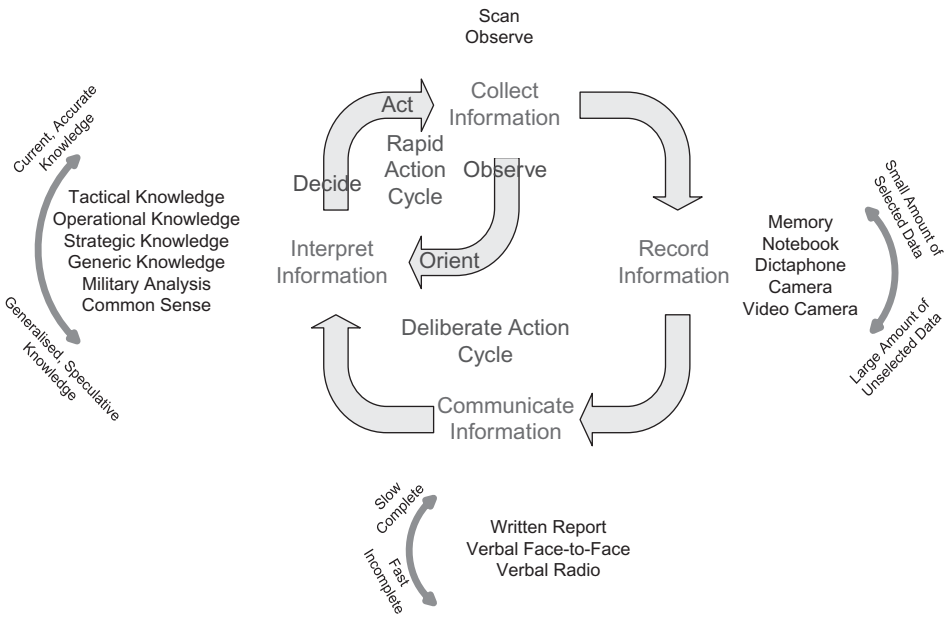


**FIGURE 2** Close target reconnaissance patrol intelligence flow diagram.

is similar to the commander's more formal estimate process after being presented with the information.

A full patrol report may take up to 3 hor to complete. Because this report is a complete account of the patrol, it is clear that no deployment of technology is required to improve the patrol's combat effectiveness. In the reality of conflict the amount of time allowed for a commander to conduct a full, doctrinal CTR is extremely rare and sacrifices have to be made to act faster then the enemy can react.

## *2. CONCEPT AND PROTOTYPE*

### *2.1. Preliminary Field Study*

Prior to development of technology, it was felt to be important to conduct preliminary trials to assess the potential impact that technology could have on the combat effectiveness of the CTR patrol. These trails could also indicate the aspects of the intelligence cycle (observe–record–communicate–interpret), other than recording, that may be affected by photography. The study involved The University of Birmingham's Officer Training Corps undertaking a low-level tactical exercise on Sennybridge Training Area, Wales. The exercise was conducted from a static patrol base and involved a variety of patrols that were run in a similar way in which troops currently patrol in major peace support operations in Afghanistan and Iraq, that is, framework or Ground Defensive Area patrols. These patrols provided an opportunity to assess the acquisition of situational awareness during a

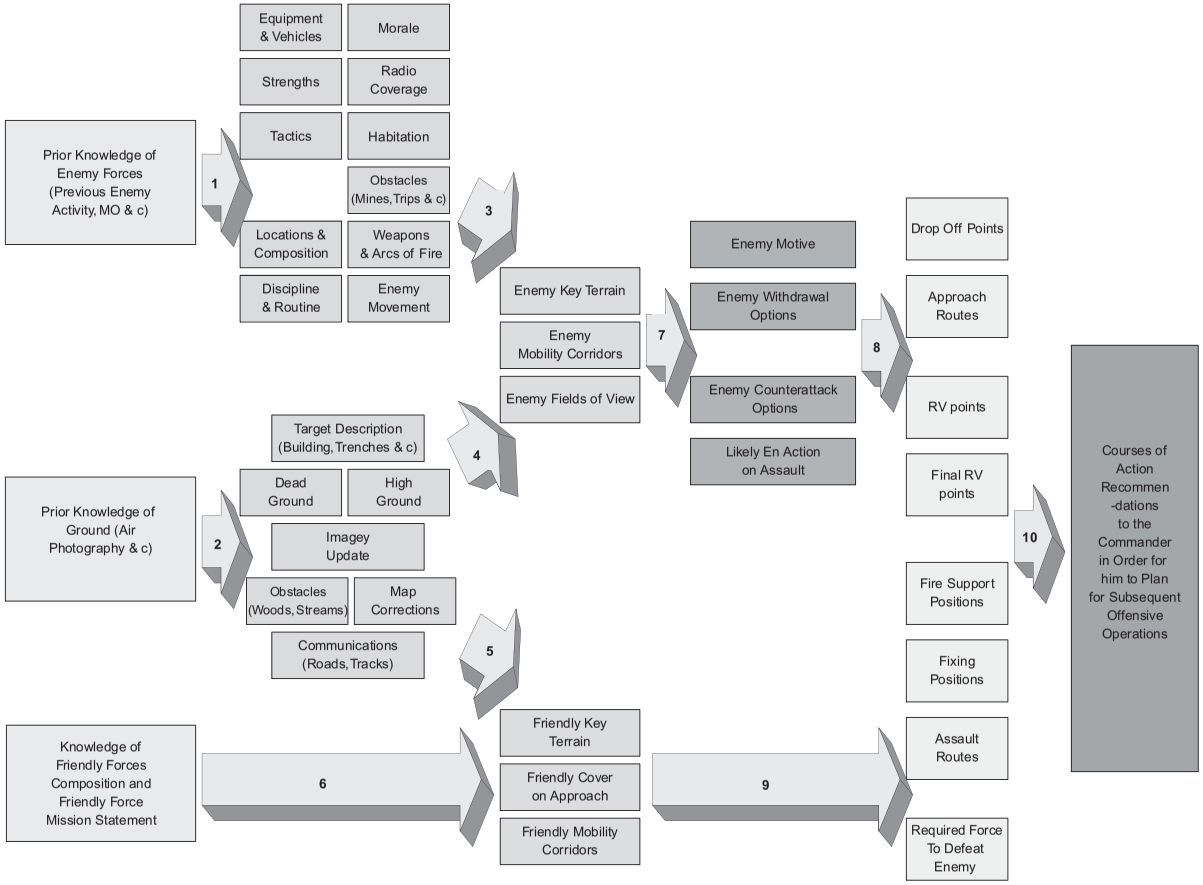


**FIGURE 3** Cognitive steps of the patrol leader to produce the reconnaissance patrol report.

patrol, the aims of the patrol being to generate or build on intelligence to produce a plan for subsequent corse of action review.

During these trials, patrols were issued with a conventional digital camera with inbuilt camera. They were asked to use the camera as they saw fit to capture images that would contribute to the patrol report, be it a written report or a verbal briefing. In total, three framework patrols and one conventional reconnaissance patrol were observed.

Broadly speaking, the captured images could be split into three categories:

- *Enemy.* Images containing information regarding the enemy
- *Terrain.* Images containing information regarding the terrain
- *Key Positions.* Specific images showing potential options for subsequent offensive operations.

***Intelligence observation.*** Giving a soldier in the patrol a camera appeared to enhance the task of observation by heightening that soldier's awareness. Due to the soldier being given a key responsibility for information capture, he may have felt pressure to produce an account of the patrol and therefore been more alert to his surroundings. The fact that images of offensive action options were captured, one of the last stages of the cognitive thought process suggests that a significant amount of thought has already been applied to image capture.

***Intelligence recording.*** With a digital camera the recording of information during the patrol occurs at the time it is witnessed. In three of the for patrols the camera operator also recorded additional informational regarding the imagery such as time and location of each image. Two of the patrols recorded further written information about each image such as an explanation of what the image showed: simple comments such as "Enemy" and "High Ground." These tags allowed each image to be classified into one of the areas already identified in the goal analysis.

***Intelligence communication.*** The images themselves were used by the commander only when specific details within the report were investigated further; for example, if the commander wished to use a certain route to approach the enemy, in two instances he requested to see any images of that route in order to validate his decision after his estimate process. It would appear that in a raw format imagery contains too much information to be communicated presenting the commander with a cognitive information overload.

***Intelligence interpretation.*** The most interesting change in the way in which intelligence is acquired occurred in the interpretation stage of the intelligence cycle. During a conventional patrol, notes are made and large amount of interpretation is conducted during the patrol; afterward, these notes are scanned together with a discussion between the all patrol members to produce the written patrol report. The cognitive workload of the patrol may be shared by allocating specific observation tasks to each patrol member in advance,

however, interpretation is largely conducted by memory. Collective memory can be dangerous and is the reason why witnesses are separated at the scene of any crime: Incomplete observations lead to the false memory to fill in the gaps and collectively can be compounded into false conclusions (Wright, Self, & Justice, 2000). With the ability to view each image prior to producing the report, the patrol leaves much of the analysis to after the patrol has finished and uses the images as the basis for discussion collectively building situational awareness from factual data.

***Conclusions.*** A number of hypotheses arise from this short study relating to the use of digital imagery to aid reconnaissance:

- Providing a patrol with a camera heightens the awareness of the camera operator and can improve observation.
- Digital images provide more detailed information than written notes.
- Imagery provides the basis for detailed and accurate analysis of information through discussion based on patrol recollection.
- Images seem to function at the level of "recognition" rather than "interpretation," that is, the camera operator might take a photograph because of a "feeling" that something of interest was present; the relatively low cognitive overhead of taking a picture (and the opportunity to delete or not use images that were not useful) meant that it was easier to take a picture than make notes.

Based on these observations location-based imagery may enhance the combat effectiveness of the CTR patrol and a sufficient case could be generated to justify the design and develop a prototype. Before explaining the prototype used in this article, the next section provides a brief overview of previous research into the concept of location-based imaging.

### *2.2. Location-Based Imaging*

Studies of location-based imaging, have typically employed purpose-built equipment that allows the user to tag an image with both its location and some additional categorization, for example, by selecting labels from a menu (Davis et al., 2005; Risto-Sarvas, Herrarte, Wilhelm, & Davis, 2004; Wilhelm, Takhteyev, Sarvas, van House, & Davis, 2004), although recent developments in mobile telephone devices mean that it might be possible to do much of this work using a product such as the HTC G1 phone (with GPS, compass, digital camera). The work by Davis and his colleagues previously mentioned was concerned with how semantic tags can be used to translate the "context" of capture (defined by location, time, and presence of other Bluetooth-enabled devices, which is used to indicate the presence of device owners when the image was captured) to define the "content" of the image. The focus of the present study is less on the mapping between context and content and more on the uses to which tagged images could be put in subsequent use of the images. Kang, Bederson, and Suh (2007) argued that "photo

metadata, such as dates, locations and content of the photos . . . play a crucial role in management and retrieval of personal photo collections" (p. 317). In this article, we suggest that photo metadata can also play significant roles in communication and decision making both at the point of capture and during subsequent use of the images.

One might view photography as an end in itself, with the product of such activity being an image. However, the motivation for capturing images is likely to vary across different contexts, for example, the reason for taking a "snapshot" taken on a night out could be to record an amusing incident, the reason for taking a photograph on holiday might be to provide a record of a trip, the reason for taking a photograph of a crime scene might be to show an item of evidence in location prior to recovery, and so on. Furthermore, a photograph may permit myriad interpretations and uses from the analytical to the aesthetic. Ways in which this interpretation can be constrained biased include the way in which a shot has been framed, its relationship with other shots (to evoke a context or category, as in a gallery collection), and the use of tags and labels either written or electronic. Following the capture and processing of the image, a photograph could become the subject of discussion (Stelmaszewska, Fields, & Blandford, 2008). We assume that the discussion will be prompted by the content of the photograph and the context of its capture. From this, we became interested in the role that photography could play in support of activities that surround the interpretation and explanation of the environment. In particular, we are interested in asking how tagged images can aid in both gathering information (by structuring the process by which information is collection) and reporting information (by automatically generating reports from the metadata for tagged images). In previous work, we explored ways in which technology can be used by crime scene examiners (Baber, Smith, Butler, Cross, & Hunter, 2008; Baber, Smith, Cross, et al., 2006; Baber, Smith, Panesar, et al., 2006b).

***Functional requirements.*** On the basis of this brief review, and the preliminary trial, we propose a set of functional requirements that a prototype should meet.

- The user interface is based on location-based image capture.
- Images can be tagged with simple information regarding their reason for capture.
- Time, location, and orientation of images are stored as part of the image meta-data.
- The user can view the images during the patrol.
- The images and metadata can be transmitted to a command module for analysis.
- The command module user is able to view the images by type, location, time, and direction of each.
- Image capture should be no more complicated than taking a photograph.

Thus, the application is seeking to provide "intuitive interaction" (Bullinger, Ziegler, & Bauer, 2002).

***Tactical requirements.*** As discussed previously, the aim of the CTR is to gain intelligence on the enemy, preferably without his knowledge, and is important that the CTR remains covert at all times. The design of the image capturing device must not, in any way, compromise the requirement for the patrol to remain covert. This requirement can be summarized in five tactical requirements:

- The device must be completely passive, emitting no electromagnetic radiation.
- The device must be small enough not to present a burden on the soldier carrying it.
- Intelligence should not be recoverable should the device fall into enemy hands.
- The device should not comprise camouflaging.
- The use of the device must not hinder the soldier's capability to use his senses in intelligence gathering or being able to react aggressively if required.

***Environmental requirements.*** CTR patrols can be conducted at night and in all weather conditions, leading to three environmental requirements:

- The device must be able to withstand water, shock and a large temperature range.
- The image capturing should be night vision capable over a range of distances.
- The device must be able to be operated for long periods on batteries.

Many of these requirements can be related to concepts surrounding mobile or ubiquitous computing (Thomas & Gellersen, 2001) or wearable computing (Baber, 2001). The question of how to present the technology relates to previous discussions by Fallman (2003), who contrasted a permanent head-mounted display with binoculars as media for presenting information to aircraft maintainers. In this article, the concept of the camera is fundamental to the application and is taken as the base analogy for development. Prior to considering this, we focus on the approach used to develop the specification.

### *2.3. Specification*

The aim of the design phase of the project was to turn the functional components of the specification into a format that is suitable for designing the user interface. A form of Unified Modelling Language, known as Object-View Interaction Design (Bardon, Berry, Bjerke, & Roberts, 2002; Roberts, Berry, Isensee, & Mullaly, 1998), was used to develop the specification. In this section, two aspects of this approach are presented to illustrate the design process.

***Use Case Diagram.*** Figure 4 shows the Use Case Diagram for the system. The Use Case is derived from consideration of the CTR patrol activity and splits the interaction of the system down into tasks. The tasks show those required of the camera module: those tasks identified by links to the patrol leader and, those tasks required of the command module, shown inside the bounding box.

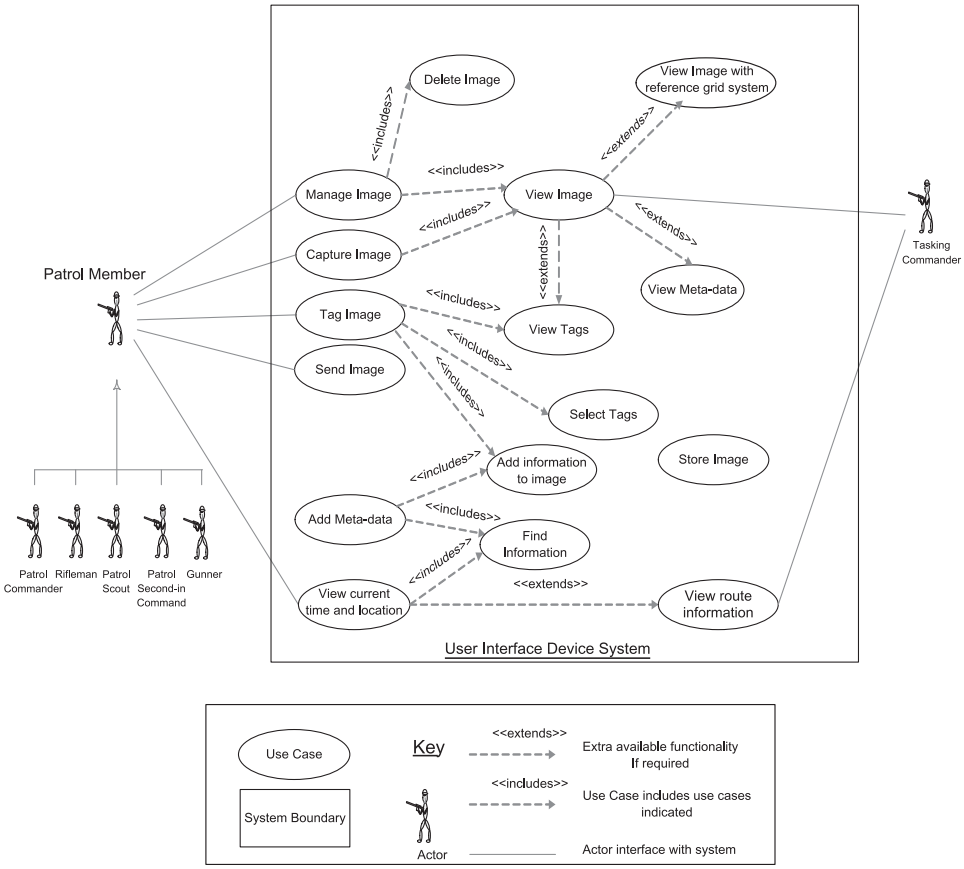


**FIGURE 4** Use Case Diagram.

***User interface environment.*** In the Object-View Interaction Design methodology, one considers the user interface environment by taking the tasks identified by the Use Case Diagram and considering how each of these tasks interact with each other. The core functions of the prototype are shown by the sequence of red arrows of Figure 5. During the capturing of an image, the image is tagged with meta-data: time, location and direction of shoot, user selected tags. During capturing, managing, and tagging, the image must be able to be viewed. The task "*manage image*" should be possible at any stage, not just after an image is captured, and this will invoke a unique image number for each image from the "store image" stage. If the user wishes to communicate the images (e.g., as attachment to an e-mail via wireless local area network or mobile phone, or as a multimedia messaging system message from the mobile telephone) then this will invoke the stored numbers from the store image stage. Each image has defined location, which can be displayed on a map on the server that receives the message. In a situation where a number of patrols are deployed viewing the route taken by each patrol gives an account of collective area covered and helps to avoid pattern

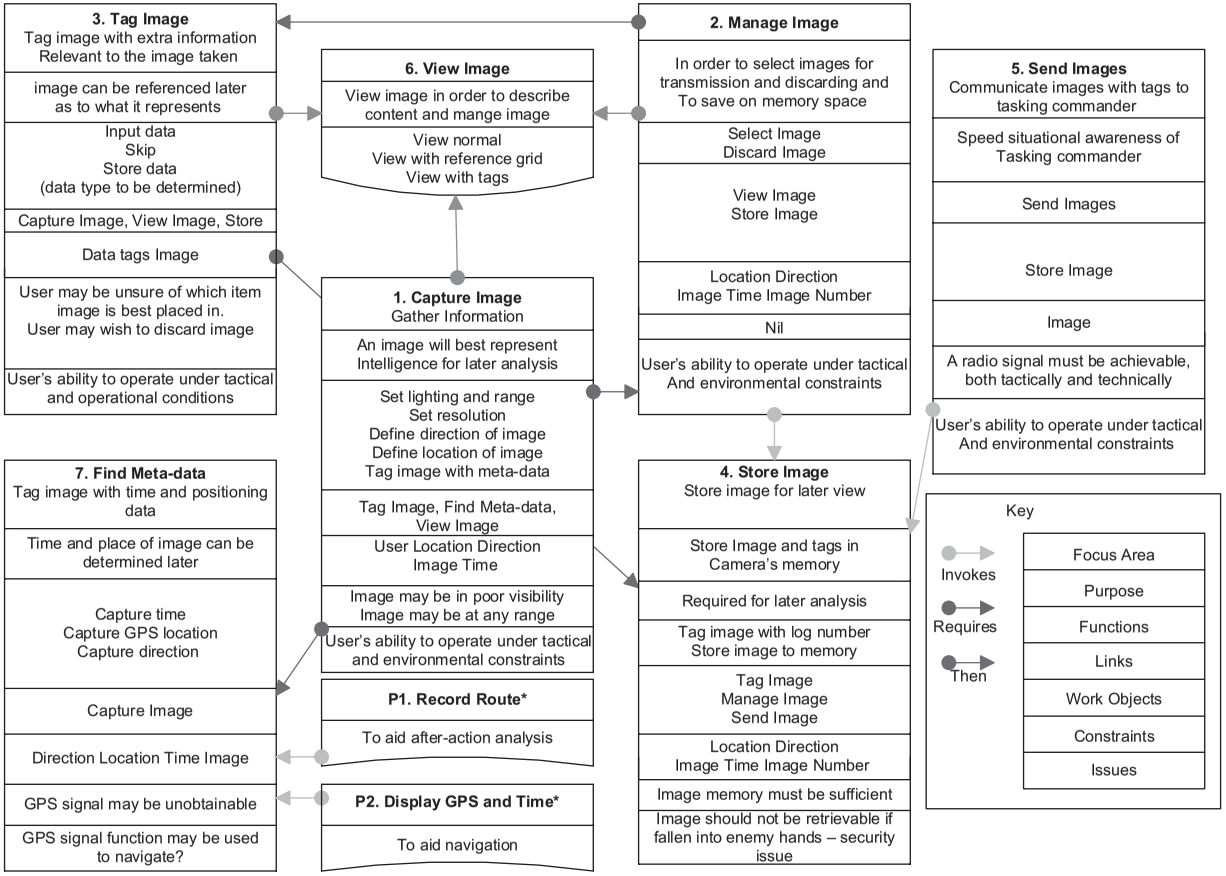


**FIGURE 5** User environment.

setting of patrol routes. In an operations room, this is currently done as each patrol returns: Each patrol leader gives a trace of his route known as an *honesty trace* on acetate; these are all superimposed on a map for further patrol leaders to consider their routes.

### 2.4. Hardware

***The camera unit.*** The camera had to be able to take pictures of sufficient quality to be able to simulate information gathering but needed to be interfaced and controlled by the Visual Basic programme. Images were captured as Video Graphics Array quality images: 640 × 480 pixel resolution, stored in a JPEG format resulting in images of around 30 to 90 kilobytes in size. To prototype the functional capability and the effect that a device may have on the mechanics of reconnaissance, a USB Creative webcam was used. In reality, the camera needed for reconnaissance would have to be high quality with zoom and night vision capability. However, it was felt that a working prototype with a commercial, off-the-shelf unit would be appropriate for this work. The webcam was first tested in isolation and then integrated into the main program using a programming method known as *CapCreateCaptureCam*. This method gives control of a part of the user interface over to the camera while the program and camera communicate by message exchange. Using *CapCreateCaptureCam* quality, size and frame rate can all be controlled.

***The GPS unit.*** The Garmin USB GPS-18, BU-353 module was used for the prototype. The various outputs of the GPS module are contained in a number of sentences that can be read by the program as required. The standard output of the GPS-18 module is in latitude and longitude based on the World Geodic System 1984 Datum (WGS84), a Cartesian system based on the standard single ellipsoid. Latitudes and longitudes are generally not used for military positioning so it was felt that the GPS-18 output should to be converted to the standard Ordnance Survey Great Britain 1936 (OSGB36) system: grid references. This process is described in *A Guide to Co-ordinate Systems in Great Britain* 2007, Ordnance Survey however involves three main stages:

- *Stage One*: Coordinate conversion from latitude and longitude to Grid Reference
- *Stage Two*: Helmert geodetic transformation from WGS84 to OSGB36. The inclusion of the Helmert geodetic transform required the geoidal height above WGS84 contained in the *Global Positioning Fix System Data* (GPGGA) sentence. This transform converts to the flatter spheroid used for British mapping and resulted in an indistinguishable error to that of a standard OSGB36 map.
- *Stage Three*: Conversion to the standard 10 figure grid reference [Ordinance Survey, 2007] Stage three uses the UK national grid system of letters to convert Eastings and Northings in metres from an origin (400k m west and 100k m north of 49ºN 2ºW) into a standard 10 figure grid prefixed by the national grid 100k m prefix, for example, SP 7523 5410 giving a East and North resolutions

of 10 m. The location of the user, captured using a Garmin USB GPS-18, BU-353 GPS receiver, corresponded to an accuracy of approximately ± 5 metres over the corse of the trials (which was felt to be acceptable for this trial, but obviously would require greater accuracy for military application).

***The compass unit.*** The compass selected for this purpose was the Devantech CMPS03 Module, the technical specifications of which are presented as Annex B. The precalibrated module works by measuring the magnetic flux in number of orientations through Phillips KMZ51 sensors and must be held away from magnetic interference and held horizontally. The sensor, on request, outputs the two-byte directional indication in the Phillips Inter-Integrated Circuit ($I^2C$) communication protocol. Conversion of this output using an $I^2C$-USB interface board allows interface with the computer program. The program is able then to manipulate the input into the more usable angular measurement of the *mil*. The mil being the standard angular measurement used by the military due to its utility in small angle indirect fire corrections. Using a standard prismatic compass as reference, the CMPS03 module was found to be accurate to around 10º / 180 mils in trial experimentation.

***Hardware platform.*** Sensor devices were connected to a Samsung Q1 tablet via USB and their data read into a VisualBasic.net application running on Microsoft Windows XP. A six-key pad (shown to the right of the Q1) allows selection of commands to operate the device. Each of the functions shown in the user environment represents a specific mode for the application, and each mode has for commands associated with it. Two further hard-wired buttons are also included: one in order to lock the device, *LOCK,* and a *BACK,* allowing the user to move back to the previous screen if the user wishes to change a selection. To take a photograph, the user selects a classification buttons at the bottom of the tablet screen (see Figure 6). The labels on these buttons can be edited to suit the application according to the specified tags. The button label, together with GPS and compass readings, were saved as XML tags to the images.


**FIGURE 6** Using the Samsung Q1 and location-based imaging.

## 3. STUDY 2: PRODUCING RECONNAISSANCE REPORTS

This study was designed to mimic some of the basic aspects of military CTR patrolling as discussed in the introduction. Rather than undertake a specifically military activity a task was designed that was conceptually similar to CTR but also of civilian interest. To this end, the study required patrols to be made of a university campus, with the aim of producing a report that would recommend traffic management solutions to improve safety for road users and pedestrians. This provided an objective that could be readily appreciated by the participants, a context of use that was operationally similar to CTR and an output that could be evaluated by available Subject Matter Experts (i.e., staff in the Estates Management department of the university).

### 3.1. Method

***Defining tags.*** Following an initial trial study, a set of tags were defined to support the patrol task. These focus on Features, Signage and Hazards, shown in Table 2.

***Procedure.*** The trials were conducted in two-person patrols using members of The University of Birmingham's Officer Training Corps. The choice of participants was influenced by the fact that they had all participated in the preliminary trials of Reconnaissance Patrols (previously reported). The mean age of the participants was 23 years, and there were 10 male and 10 female participants. Trials were conducted in pairs: One of the students acted as patrol leader with overall responsible for the delivery of the patrol report and the other student took responsibility for recording information during the patrol. Students were paid for their participation. Participant motivation was enhanced by a prize awarded for the best report in each trial set. Each pair of participants was randomly assigned to one of two conditions; either recording their observations with pencil, paper and map or using the location-based imaging prototype. In both conditions each trial was conducted in the following phases:

**Table 2: Tags**

| *Features* | *Signage* | *Hazards* |
|---|---|---|
| Traffic lights | Orders signs | Surface hazard |
| Road crossings | Instructions signs | Visibility hazard |
| Road works | Warning signs | Speed hazard |
| Road markings | Direction signs | Obstruction hazard |
| Speed control | Information signs | Congestion hazard |
| Roundabouts | | |
| Barriers | | |
| Road surfacing | | |
| Pedestrian paths | | |
| Miscellaneous | | |

- *Orders.* Explanation of the rationale of the trials and the issue of orders for the patrol, outlining the main objectives for the patrol and advisable routes.
- *Background Information.* The issue of route maps, Highway Code details of road signs and lists of tags.
- *Equipment Training and Practice.* A short period of system training for the participants using the equipment, and a similar duration of training on report collection for the paper condition.
- *Patrol.* 1 hr 45 min was then given to the participants to plan the patrol, conduct the patrol within the given area, and deliver the patrol report.

The participants undertaking the digital photographic trials were allowed to reference any material that they had gathered through imagery in their reports; however, they did not use the images directly as part of the reports. This was intended to ensure a degree of parsimony in final reports to minimize the risk of the assessor analyzing the images directly and forming their own interpretation.

### 3.2. Results

***Activity duration.*** The activity was broken into three phases: plan, execute, and report. There is no difference between conditions in the time spent planning the patrol, $t(9) = 1.95$, $p = .08$. There was no difference in length of time spent conducting the patrol (54 (±7) min for the pencil, paper, and map condition vs. 51(±14) min for the location-based imaging condition), $t(9) = 1.01$, $p = .34$. This is important because it shows that the act of taking a photograph, or making notes, did not affect the total time taken to complete the patrol. There was, however, a significant difference in duration of the ensuing report writing activity 31(±7) min for the pencil, paper, and map condition versus 44 (±10) min for the location-based imaging condition, $t(9) = 2.4$, $p = .04$.

***Patrol report content analysis.*** To assess the effectiveness of the patrols, the patrol reports were subjected to a form of content analysis. Items in the report were classified as being primarily statements of *perception*, or *interpretation*, or *conclusions*. Perception was classified as site-specific statements (e.g., a traffic sign at a particular junction) or general statements (e.g., the volume of traffic around the campus). The location-based imaging condition produced significantly more site-specific statements ($U = 0$, $p = .004$) than the pencil, paper, and map condition. There were no differences between conditions in terms of general statements ($U = 14.5$, $p = .58$). The location-based imaging conditions produced significantly more *conclusions* than the pencil, paper, and map condition ($U = 4$, $p = .025$).

***Patrol report structural analysis.*** Having classified the content of the patrol reports, we investigated the relationships between types of statement (i.e., perception, interpretation, conclusions). The reason for this is to determine how each type of statement influenced subsequent statements in the patrol report. Statements relating to perception of features in the environment could be used to explain or justify

interpretations, which, in turn, could be used to defend recommendations. Thus, a well-reasoned recommendation would draw on interpretation of perception of features to provide support for it. A poorly reasoned recommendation, in contrast, would make little or no reference to perceptions or interpretations. There was a small (but nonsignificant) difference across conditions in the link between perception and interpretation, that is, the ability to interpret information captured in the world ($U = 7$, $p = .078$). The previous analysis shows that the participants in the digital photography condition collected more evidence of items in the world, and this could simply influence the use of such information. There is little difference between conditions in terms of the participant's use of perceptions to support conclusions ($U = 8$, $p = .11$). This could be that all participants were equally able to consider a site-specific comment, such as "sign broken" and suggest a conclusion (i.e., "repair sign"). However, participants in the location-based imaging condition were significantly better able to relate interpretation to conclusions ($U = 3.5$, $p = .02$). The implication is that the location-based imaging condition supported a logical and auditable process of analysis such that the interpretation of evidence was used as the basis for the conclusions.

***Relating performance in this study to sense-making.*** Table 3 compares the two conditions in terms of sense-making. In particular, one can see a difference in this issue of plausibility when comparing the pencil, paper, and map condition and location-based imaging condition: participants in the pencil, paper, and map condition tended to apply plausible interpretations to the environment during their note-taking and then used these notes to structure their reports, whereas participants in the location-based imaging condition would often capture images that looked of interest and then define plausible interpretations during report writing. From this observation, participants in the location-based imaging condition tended not to commit themselves to interpretations until they were writing the report, whereas those in the pencil, paper, and map condition had reached a conclusion during their patrolling.

### 3.3. Conclusions

This study has demonstrated superior performance in a report-writing task when participants captured images rather than taking notes in situ, specifically in terms of producing well-reasoned recommendations. At one level, this could simply mean that the act of writing notes could be more cognitively demanding than that of taking a photograph, and this could mean that the level of detail in the notes was not sufficient to support the report writing. At another level, we feel that there is a sense in which the act of writing a note is an interpretive act and that this provides a closure for the interpretation of a given setting. In contrast, the capture of an image could be defined by the intention to use it later. From this perspective, a photograph becomes a form of "note-taking" in which the person is not committed to a specific interpretation.

The comparison of performance times in this trial implies little difference between groups in terms of conducting the patrols but some difference in terms of

**Table 3: Comparison of Conditions in Study 2**

| *Sense-Making Property* | *Pen & Paper Control Group* | *Photograph Group* |
|---|---|---|
| Grounded in identity construction | Recorder of opinions on road hazards generated by commander | Sampler of environment recording items indicated by the commander |
| Retrospective | Hazards identified for subsequent compilation | Photographs taken for post hoc analysis |
| Enactive of sensible environments | Capture of hazards defined by patrol leader with features of the environment only occasionally mentioned as supporting evidence | Capture of road signs, street furniture, crossings, road markings etc under direction by patrol leader |
| Social | Interaction between commander and scribe largely took the form of dictation with some editing carried out in the report writing phase | Interaction between commander and scribe took the form of directed photograph taking, in some cases the dictation of extra labels and discussion by both parties to reinterpret the images in the report writing phase |
| Ongoing | Order of hazards identified in the report broadly followed the route taken during field work | Order of report was typically related to the hazards identified |
| Focused on and by extracted cues | Cues were used in the field but not recorded for later analysis | Many cues captured during field work; analysis/report writing phases involved ordering and sorting of these cues by geographical location and subsequent identification of hazard types |
| Driven by plausibility rather than accuracy | Final report was based on a compilation of hazards identified in the field and so there was relatively effort made toward or possibility of resolving inconsistencies as the audit trail was not itself present for their identification | Effort was made to reconcile interpretations of cues based on attempting to find consistency amongst them at the analysis stage. Inconsistencies were detectable through identification of additional information in photographs |

writing the reports. This difference could be explained by time spent reviewing and interpreting the images. It was interesting to observe the manner in which the two groups tended to approach the process of report-writing. Although they shared a common focus on relating the information captured to a map of their route, the group using written notes tended to compile these notes into a report with little additional information; the process of writing the report was seen as something to be performed in parallel with patrolling. For the location-based imaging condition, the report writing was performed post hoc, which helped retain flexibility in interpretation. The group using images would review the images more than once, typically using the tags they had provided to cue the combination of images to view. In this way, the images would be viewed not only more than once but also in combination with other images that had the same tag. This could have helped generate associations and ideas that linked the images and led to more detailed interpretation and recommendations.

## 4. DISCUSSION

If one accepts the CTR patrols exhibit elements of RPDM, then having a technology that essentially provides the opportunity to capture features that *might* be significant (together with some means of tagging that capture for later consideration) could be beneficial. The study showed better report writing when using location-based photography and this was felt to be due to two factors:

1. The act of taking a photograph is not necessarily interpretative but it is purposeful. This accords well with the notion of RPD in that taking a photograph need not involve the person in the level of analysis required for making notes. In this manner, taking a photograph could be considered similar to pointing out interesting features in the environment without necessarily having to explain why these are interesting.
2. Having taken a photograph, the act of interpretation can be deferred. This differs from note-taking, which tends to combines interpretation with recording. We note that participants in the location-based imaging condition tended to reuse photographs by grouping them under their different tags, which provided an opportunity to revisit different issues and explore the photographs in different ways. The participants in note-taking condition tended to rely on their notes, often in the order in which they had been written and included less additional information.

The study implied some consistency in the use of images and demonstrated that the use of location-based photography led to superior performance when compared with the use of written notes. One suggestion is that the practice of note-taking in the environment leads to a sense of "closure" for the task, in that participants felt that the interpretation of the environment at that location was complete. This meant that the report writing involved the compilation of these notes into a report, with little additional information. Image capture, on the other hand, delays interpretation and participants used the tagged images to look for patterns and combinations of information to support their report writing. Thus, location-based image capture can support the interpretation of the environment, and the use of tagged images might be superior to written notes.

It is plausible that the studies could have been conducted without the use of location-based photography, but with a handwritten list of when and where photographs were taken. However, we note that the provision of tagging did *not* hamper image in any obvious manner; by which we mean that asking users to press more than one button to capture an image (to provide a tag) was not commented upon as being cumbersome or interfering with the capture of the image. Furthermore, Study 2 in particular showed how the tags allowed users to revisit images in different contexts (defined by the tags they had originally allocated). Thus, tagging could be seen as a convenient means of relating images and did not seem to interfere with image capture. The use of location-based imaging in the study seemed have the effect of structuring the patrol in line with the intelligence cycle and allow more accurate interpretation due to less reliance on memory after the patrol. Three explanations are proposed as to why the location-based imaging

condition produced more detailed reports in the same period than those patrols using pen and paper:

- *Organized Intelligence Observation*: The use tagged-images organizes the observational tasks. Without this organization and due to the large amount of information throughout all levels of situational awareness, observation is disorganized and includes a significant amount of premature localized intelligence analysis. The lack of focused observation and analysis of intelligence during the patrol results in key information being missed.
- *Standardized Intelligence Recording*: Use of the camera takes care of intelligence recording and only simple written notes need to be added to the metadata allowing less distraction to observation.
- *Systematic Intelligence Analysis*: Analysis can be conducted by viewing aggregated and positioned intelligence in tag groups on the command module after the patrol. The use of the images as an aid of memory also ensures that intelligence is analyzed and interpreted accurately rather than relying on disorganized notes and potentially false collective memory.

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