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Detect the unexpected: a science for surveillance.

Conceptual Paper.

Keywords: Cognitive Social Psychology, Surveillance, Violence, Safety.

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Abstract

Purpose

This paper outlines a strategy for research development focused on addressing the neglected role of visual perception in real life tasks such as policing surveillance and command and control settings. Perception is much less well documented and investigated than the roles of social psychology or memory in general policing research, both of which are well established and have led to changes in policing policy procedure and practice.

Approach

The scale of surveillance task in modern control room is expanding as technology increases input capacity at an accelerating rate. We review recent literature highlighting the difficulties that apply to modern surveillance and give examples of how poor detection of the unexpected can be, and how surprising this deficit can be. Perceptual phenomena such as Change Blindness are linked to the perceptual processes undertaken by law-enforcement personnel.

Practical implications

We outline a scientific programme for how detection deficits can best be addressed in the context of a multidisciplinary collaborative agenda between researchers and practitioners. The development of a cognitive research field specifically examining the occurrence of perceptual 'failures' provides an opportunity for policing agencies to relate laboratory findings in psychology to their own fields of day-to-day enquiry.

Originality/value of paper

We show, with examples, where interdisciplinary research may best be focussed on evaluating practical solutions and on generating useable guidelines on procedure and practice. We argue that these processes should be investigated in real and simulated context-specific studies to confirm the validity of the findings in these new applied scenarios.

[Abstract 250 Words, including headings.]

Introduction

Readers who have worked in, or visited a control room will testify to the large amount of data that is being processed by operation team group members in auditory and visual formats. This environment produces visual load at both the *macro* and the *micro* levels of analysis. On the one hand, individual monitoring of single visual sources such as TV monitors (the micro level) provides, alongside audio, the raw data for any command and control room; on the other hand, executive oversight of huge amounts of information, much of it visual, is required by commanders to facilitate effective resource management (the *macro* level). Layered on top of this are operational concerns about both short- and long-term accountability. These accountability issues place an additional constraint on decision making at strategic, tactical and operational levels.

Such control-room operations place a huge demand on the human visual system, yet almost all of our visual processing is seemingly effortless and automatic. We feel as though we see the world in its infinite richness and technicolour detail. Indeed, much of the research literature in this area about basic visual perceptions centres on the complex sensitivity of the human visual system (e.g. Graham, 1989). We are able to recognise and name thousands of faces, recall many more thousands of scenes from visual memory and detect minute changes in orientation, brightness or alignment. This overarching feeling of visual completeness can unfortunately lead to an overestimation of our visual abilities. In this paper we show how cognitive science allows us to begin to quantify just how justified is our implicit faith in the human visual system. We then examine to what extent a scientific approach to the human and technological factors surrounding the development of a scalable approach to volume surveillance can inform and improve homeland security. We argue that this can be achieved via an analytic approach to the transfer of information from first responder to an incident to the overall strategic and tactical command.

Limitations of human perception in surveillance: Change Blindness.

A recent and growing body of literature has highlighted rather surprising failures in visual perception – so called 'change blindness' (Rensink, O'Regan & Clark, 1997; Rensink, 2002; Simons and Rensink, 2005). A demonstration typically involves introducing unexpected changes to visual scenes. Contrary to observers' own expectations, changes introduced during blinks, flickers, or disruptions can be very hard to spot. What distinguishes the demonstrations of these *lapses* in visual performance from previous literature (showing the notable *achievements* of visual performance) is that they are typically demonstrated with naturalistic scenes; this contrasts with the stylised arrays of primitive objects normally used by cognitive scientists. Despite (or perhaps because of) the familiarity of the scene, observers are surprised when they cannot easily detect changes introduced to the scenarios. For example a typical demonstration involves the presentation of flickering scene on a TV screen; every alternate presentation of the scene incorporates a change to the scene (such as removal of an object from the scene). Provided the scene flickers are interspersed with short grey blank intervals, it can be infuriatingly difficult to spot that something as obvious as an aeroplane engine, a tree, or an animal has been 'photoshopped' from the picture (Rensink *et al*., 1997)[1].

These demonstrations may not immediately appear to be relevant to the tasks of observers in CCTV control rooms. However, the crucial determinant of whether or not these 'changes' are detected is the amount of visual disruption used. Blinks (Grimes, 1996), blanks (Rensink et al, 1997) and other transient 'splashes' (O'Regan *et al*., 1999) appear to devastate the visual system resulting in a surprising loss of visual detection performance. In this context, the average CCTV system can be considered as a ‘change blindness’ machine. By necessity the system must flick between multiple views of a complex scene to try and capture as much information as possible. The decoupling of space and time that this introduces, makes perception of events much harder than we might expect from our own performance in ‘the real world’ (i.e. with single viewpoint, full uninterrupted views). The same paradigm has been used to demonstrate surprising levels of performance decrements for changes in road traffic scenes (e.g. Caird, Edwards, Creaser and Horrey, 2005). It was the work of Grimes (1996) that showed just how pervasive change blindness could potentially be, changes made literally during the blink of an eye (using sophisticated eye-tracking technology) rendered large scene changes undetectable.

Inattentional Blindness

One form of ‘change blindness’ is ‘inattentional blindness’ (Mack and Rock, 1998) and perhaps the most famous demonstration of inattentional blindness is the widely publicised ‘Gorillas in our Midst’ experiment by Simons and Chabris (1999). A number of viewers of a basketball game were asked to engage in a simple video monitoring task (counting the number of passes made by the white team during the game). This lead to a focussing of attention strong enough to result in the viewers’ failure to spot a person in a gorilla suit walking over to the middle of the court, beating its chest, then walking off. Viewers allowed to simply watch the game, unencumbered with an additional task, spotted the gorilla straight away. Likewise, viewers concentrating on the pass completions of the black shirted team also readily spotted the gorilla. In the context of these widely replicated research findings (e.g.

Levin, Simons, Angelone, & Chabris; 2002) the relationship to this rather amusing seemingly innocuous demonstration becomes clearer. The following two examples will help cement the idea for the reader to understand the relevance of this scientific phenomenon to police and other agents of social control. On the one hand, surveillance techniques have been shown to be dramatically successful at identifying hard to spot people and incidents (e.g. identifying the London Bombers from thousands of hours of videotape (Knight, 2005)). On the other hand, when observers are *overly* focussed on certain aspects of a vigilance task they can miss obvious clues to criminal activity. The misdirection of attention accidentally induced by the media during the Washington Sniper crisis (Coppola, 2005) is a dramatic case in point: a white van reported to be linked to the snipers proved to be a complete red herring and diverted valuable resources and attention away from the blue sedan driven by the two men responsible.

Change Blindness Blindness

Rather worryingly, even after people are made aware of these widely documented 'failures' of perception arising from change blindness and even once they have experienced them themselves, they still overestimate their ability to detect unexpected changes, by as much as 30%, (Levin, Momen, Drivdahl, & Simons, 2000). Levin *et al.*, (2000) call this overestimation *'change blindness' blindness*. Some might say that this misperception may only arise through the bizarre nature of some of the changes used in these demonstrations. However, subsequent 'live-action' experiments (e.g. Angelone, Levin, & Simons, 2003) have used more conventional changes familiar to practitioner contexts: namely, object 'removal' (theft) and person-changes (identity-swops during victim distraction). The links with theft and the use of disguise to avoid detection and apprehension are more obvious when members of the public are engaged in 'live-action' swaps of conversation partners such as these [2]. Such credibility criticisms might also been levelled at the photographic demonstrations of change blindness (e.g. Rensink *et al*., 1997). In real life, it could be argued that scenes do not rapidly alternate every fraction of a second – and the inability to detect such changes is neither surprising nor problematic. However, the modern environment is much less predictable and stable than the forest or savannah environment that our visual system evolved to deal with (Barkow, Cosmides and Tooby, 1992; Walls, 1967). Modern computer operating systems, CCTV systems and TV-channels can all switch between many different outputs in the blink of an eye – a perfect environment for change blindness. Even in situations when we are aware that there may be the possibility of change blindness, because of our natural overconfidence ('change blindness' blindness) we are still liable to miss dramatic changes in visual scenes (Levin *et al*. 2000). A classic example of this phenomenon is the Fathers for Justice campaigners who managed to penetrate surprisingly far into secure parts of London wearing highly conspicuous superhero costumes (e.g. Johnston and Alleyne, 2004).

The examples above might serve to dishearten the practitioner**,** when faced with surprising examples of the potential weakness and vulnerability of any observation based system. However, the above examples also demonstrate the long-term solution for dealing with these issues: namely the revelation of the fact that these phenomena are amenable to psychological investigation and quantification. Seemingly abstract and intangible processes can be described and quantified with appropriate techniques. Once understood, interventions can be implemented to mitigate the worst effects of these phenomena. For example, Rensink (2000) has shown that the feeling of perceiving a change, 'without quite knowing what the change might be', is measurable. In what he rather cleverly terms 'mindsight', he used a change blindness flicker paradigm that initially contained no change between flickered presentations of the scene. Then, after a predetermined number of alterations, a change was introduced and participants were asked to make two key presses: one when they thought that a change occurred, another when they had identified it. This experimental paradigm indicated that there is a delay of several seconds between the initial awareness of 'a' change and the final conscious detection of the nature of the change. It is as if the gut feeling exists prior to conscious recognition.

As we have seen above, Cognitive Sciences can begin to document, quantify and estimate the extent of previously intractable psychological processes. Gladwell (2005) provides a very accessible introduction point for the development of a view of the pros and cons of relying on these 'gut feelings' in perceptual judgments and he calls the rapid initial formation of such opinions 'thin slicing' (i.e. taking an expert, but quickly formed, judgement). In particular he shows how broader themes in human judgment are beginning to be tapped into by Cognitive Sciences. Once documented and delineated, suitable interventions or solutions can then be developed and tested.

The applied cognitive psychology approach has already served and continues to serve the non-visual aspects of policing, for example in relation to witness testimony a quantitative, scientific approach has delivered tangible innovations in procedure and practice in the context of human memory. From an evidential point of view, the very nature of *retrieving* memories can, it seems, induce *forgetting* of related memory representations (e.g. Anderson, Bjork and Bjork, 1994; Shaw, Bjork and Handal, 1995). The most relevant example of this is the finding that having viewed a scene (say a 'crime scene' of a college dormitory) subsequent repeated retrieval practice of a subset of items (e.g., Harvard college sweaters) to be learned from within a category of objects (e.g. college sweaters) reduced recall performance for unpracticed items in the same category. Recall for items from different categories (e.g., college books) remained unaffected by the additional practice (Shaw, Bjork and Handal, 1995). On a practical level this puts observers in a position where ongoing sequences of surveillance and pursuit may produce unexpected impairments in performance, impairments that would not necessarily be apparent in subsequent debriefs or in court. Clearly this can have potentially catastrophic consequences to the overall outcomes in cases reliant on witness testimony. However, more recent research highlights the more subtle nature of this phenomenon. MacLeod and Macrae (2001) have shown how separation of guided retrieval practice from a final recall test can eliminate the incidence of 'retrieval-induced forgetting'. This has implications for the way that overt and covert surveillance in all its forms is implemented. In particular the selection of material appropriate for dissemination and transmission between operatives is crucial, yet the efficacy of different types of information is still poorly understood. Only a systematic exploration of this phenomenon in realistic (ecologically valid) surveillance and pursuit contexts will reveal the extent of the problem and the possible solutions.

A Scientific Approach to Surveillance

In this section we review the applicability of attention-related psychological concepts, phenomena and findings to the research agenda for effective surveillance in modern society. In the same way that additional recall items have a cost in the context of retrieval induced forgetting (as discussed above), each and every item that is transmitted throughout the command chain has an associated potential cost. The more (possibly unnecessary) extra information that is passed on, the greater the possibility there is of over-focusing on potentially misleading or irrelevant information. For example, if appearance in a target is incorrectly identified or recalled, then the potential exists for spectacular misdirection of attention (e.g. Gorillas in our midst (Simons and Chabris, 1999), Washington Sniper (Coppola, 2005)). Over-focusing is broad topic but at least part of it has been the subject of systematic applied research under the term of ‘attentional set’ (e.g., Most, Scholl, Clifford, & Simons, 2005). Essentially, this is the notion that observers can simplify a task by focusing attention into a reduced (relatively manageable) subset of objects for scrutiny in a complex scene. The relevance attentional set in vigilance related tasks (e.g. vehicle driving) has been clearly demonstrated by Most and Astur (2007). In their experiment, participants were asked to navigate by obeying directions indicated by either a yellow or a blue turn-sign appearing at intersections in the driving simulator that they were using. At a subsequent intersection either a blue or a yellow motorcycle would unexpectedly career into their path and block the road. Bikes that did not match attentional set (i.e. bikes with a non-congruent colour to the target) were detected less quickly leading to substantially greater collisions rates in those non-congruent conditions. This shows how from moment to moment, the attentional set of the observer can influence the uptake of information from the visual array, much like the observers in Simons and Chabris (1999) Gorilla experiment who were tracking the passes from the white team. These observers were least likely to spot the unexpected event (the black gorilla).

Caird, Edwards, Creaser, Horrey (2005) have shown a much more long-term influence of attentional set using a very similar paradigm. Again in the domain of traffic scene perception they used a variation of Rensink et al’s (1997) ‘flicker paradigm’ to probe the decision accuracy of observers for changes to the pictorial information contained in photographs of traffic intersections. Changes consisted of alterations to a single object: either a pedestrian, a vehicle, a sign or a traffic control device. Older participants showed reduced levels of accuracy in 'go/no-go' decisions for photographs of traffic intersections. In particular, older drivers appeared to show more reliance on traffic control devices at the expense of other types of hazards. Additional inspection time served to mitigate against the likelihood of decision errors, fortunately. The full explanation of the mechanism underlying this result is still a matter of debate, but the relevance to surveillance is clear. Age and experience dramatically influence the way that observers see the world (based on the expected likelihood of possible events); this influence can be malign or benign depending on the training, experience and circumstances of the viewing.

We have seen how dramatically perception can 'fail' our expectations. Fortunately the incidence of these failures (or more properly 'misperceptions') can be assessed and quantified. Optimal viewing conditions can make items, that might otherwise be invisible, trivially easy to spot. Within the population, individual differences in performance on such vigilance tasks clearly exist based on experience; and this means that appropriate training should enhance overall performance. Accordingly we propose that a coordinated research endeavour uniting academia and the policing community be developed to tackle the issue of misperception with a view to generating innovation in policy, procedure and practice.

Recent research has attempted to tackle closely related training issues in a multidisciplinary approach by looking in detail at the way in which 'field settings' can be re/created in virtual reality contexts e.g. immersion labs (e.g., Christou, and Bulthoff, 2000; Reicher, Sani, Cassidy and Cronin, 2004). 'Visual immersion' is the key tool to promote a feeling of 'presence' in participants– to make them feel as though they are fully engaged in a realistic approximation of reality (e.g., see Lombard & Ditton (1997) for a review of the concept of 'presence' in virtual environments). Visual immersion is achieved by using large-scale projection screens on multiple walls of the laboratory. The experience of realism is further enhanced by the use of sound amplification, which permits the exploration of the complexity of multi-modal presentation and its effects on perceptual processing. The ability to present hi-resolution broadcast quality visuals in real-time to the immersion lab (and to record the participants responses) allows for accurate portrayal of 'high-stakes' fast-time decision making policing and detection tasks as experienced in real world situations. Following the simulation, the participants can then be shown an instant replay of their actions with full 20:20 hindsight. This allows immediate feedback on complex decision and action tasks. In addition, post-incident scrutiny can be played out over a much-extended timeline and thus decisions made in the heat of the moment can be inspected and vindicated (or made to look spectacularly unfounded in the harsh light of repeated playback). This technology is being put to use in the context of firearms training (e.g. Roberston, Bown, Robinson & Cronin, 2007) where officers in the so-called 'shoot/no-shoot dilemma' have literally a split second to make a decision to discharge a weapon or not.

A similar, controlled, methodology for analysing more general decision making in real-time using realistic contexts can in principle be achieved by the development of CCTV control room 'simulators'. Whilst there will always be natural scepticism from existing staff over the efficacy of such simulators, the potential benefits for training are considerable. Flight simulators are now considered and accepted (e.g., Caro, 1988; Moore, 2006) as essential components of crew training. The scope for creating unexpected events in unfolding situations, tied to the facility of recording and reviewing crew interactions have proved invaluable in the development and enhancement of crew procedure and practice (e.g., North and Woodling, 1970; Foushee and Helmreich, 1988). The lessons from many years worth of vigilance research must be heeded in the development of a science of surveillance. In particular the good practice learned in mission-critical operations rooms such as radar centres, air-traffic control rooms etc. should continue to inform and develop the construction and management of CCTV control rooms.

The problems for CCTV rooms are different to those facing more traditional areas of the vigilance literature however. This is due to the ever-increasing diversity of potential threats arising from international/domestic terrorism and the widening scope and variety of visual evidence to be scrutinised. Measuring the efficiency and effectiveness of a CCTV control room team and system as whole is fraught with difficulty but the issues arising in this type of activity are now the focus of attention of mainstream science. The emergence of the field of ‘Visual Analytics’ (Thomas and Cook, 2005) has served to delineate the conceptual and practical issues involved in protecting US homeland security using the full panoply of data created by modern social institutions. This move to maximise the utility of data streams is also a US based National Science Foundation / National Institutes of Health priority (Johnson, Moorhead, Munzner, Pfister, Rheingans, & Yoo, 2006). The new research teams being formed to research these areas cross the traditional boundaries of disciplines within science. In order to deliver the applied research benefits there needs to be a similar avoidance of artificial boundaries within the law-enforcement communities. The successful implementation will involve massive levels of data sharing, inter-agency cooperation and cross-jurisdictional collaboration.

The recent UK legal proceedings surrounding the death of Jean Charles de Menezes has brought the issue of control room accountability (Cronin and Reicher, 2006) into sharp relief. Investigators were concerned with the possibility of the noise of the busy control room adversely affecting the decision making of the senior officers charged with controlling the operation (IPCC, 2007). The combination of these external stressors combined with the intrinsic stressor of the difficult job in hand certainly would be expected to influence decision-making (Cronin, 2001). Results from existing literature are difficult to extrapolate to control room contexts because of the lack of applied research in this area, but battle planning simulations and flight simulation studies are relevant (Baldwin, 1994). However, because technology has transformed control rooms so much in the last 10 years, the fundamental perceptual and decision tasks are new. The information streams feeding into control rooms are multi-modal: the principal obvious change is the use of the ‘video-wall’ comprising multiple CCTV monitors situated at one end of a control room (in addition to a personal observation monitor). The increase in visual load is dramatic compared to pre-CCTV control rooms. The task of Visual Analytics (e.g., Thomas and Cook, 2005) is to present the information in the optimal format. This format must incorporate information from multiple sound channels (telephones, camera feed, junior officers, surveillance teams, firearms teams) as well as the crucial video streams (minus the distractors).

Effective use of ‘video-walls’ has only very recently come under widespread controlled investigation. In the context of aviation monitoring, Wickens, Muthard, Alexander, Van Olffen, Podczerwinski, (2003) have examined the influences of display visibility as a function of display-size and event-eccentricity (i.e., visibility for items viewed ‘out of the corner of the eye’). Display size does not appear to degrade change detection *per se*, however, there is some evidence that hazard information presented at the periphery may be less easily spotted in extensive visual display formats (Wickens *et al*., 2003). Polys, Kim, & Bowman (2007) found that certain search tasks were better on widescreen views (despite the greater retinal eccentricity) of items in the periphery. Comparison tasks seem to be easier on smaller views (this finding is consistent with basic psychophysical research (e.g. Scott-Brown, Baker and Orbach, 2000)). Investigations are only now beginning to take account of the hitherto neglected role of eye-gaze patterns of CCTV operators on multi-screen displays during monitoring tasks (e.g., Troscianko, Gregory, Hawker, Bhatt, Porter, Lovell & Meese, 2007).

The type of multidisciplinary applied research paradigms we have been discussing can and should be extended to the role of colour perception in surveillance. Over the past 10 years there has been a race to renew and upgrade CCTV systems to colour systems thanks to the belief that they will offer superior performance over their monochrome ancestors (Davies and Thasen, 2000). However the empirical evidence on face recognition performance suggests that no measurable benefits accrue with colour rendering (Bruce, Henderson, Greenwood, Hancock, Burton, & Miller, 1999). Despite this, it is assumed that identification performance for other aspects of the scene will be superior (such as in the description of clothes for example – 'suspect is wearing a green jacket'). Under conditions of poor lighting, however, anecdotal evidence suggests that operators prefer monochrome settings to improve visibility and reduce confusability (personal observations from interviews with practitioners conducted by the authors). Under the restricted light wavelength emitted by sodium streetlights, and fluorescent shop lights, it is possible that colour CCTV footage may in fact impair the ability to accurately describe clothing and other relevant suspect information.

A substantial body of literature on expertise in sustained vigilance emerged largely as a result of the introduction of radar defence systems in the World War II (e.g., Mackworth, 1969; Ware, Baker, and Drucker, 1964). Radar represented an unusual challenge for human observers, namely one of watching an abstract display for many hours searching for minute changes in displays. Much has been learned about effective shift patterns and patterns of relief to enable sustained vigilance to be effective. Lifeguards at swimming pools are probably the most readily recognisable example of this expertise, with regular changes in 'sentry' duty designed to relieve the boredom of the task. Even in this task, mistakes do continue to happen and seemingly obvious incidents do occasionally go undetected (Urquhart, 2007). However the nature of the modern control room tasks mean that the scope of the vigilance task is much wider than the tasks previously studies (e.g. Caird *et al*., 2005). Hence, not all of the pre-existing literature is generalisable to this new form of surveillance. For example, the excellent work relating the differential loads placed on vigilance tasks by spatial and verbal working memory are documented by Caggiano and Parasuraman (2004) (amongst others) but the vigilance task in their experiment is simply to detect the change in orientation of a wrench.

Practical, Training and Operational Implications

In this section we show how the concepts reviewed above can be translated to policing related policy procedure and practice in surveillance related tasks such as control rooms. Unfortunately, the primary CCTV surveillance operator task is not perceived as high value (unlike a radar operator in World War II where errors of omission were disastrous), nor is it perceived as glamorous, high profile, or high in social status. As a result, shift patterns in these roles reflect standard employment patterns in a ‘long-hours culture’, rather than reflecting the most appropriate allocation for the skilled task in hand. For example, a prototypical provincial control room would have a permanent staff of around 10 operators working a 37 hour week each meaning that probably at any time there are two individuals responsible for around 50 cameras. In a year this would typically face approximately 700 community safety incidents, leading to around 150 evidential tape submissions relating to about 60 arrests, with around 1/3 of these directly attributable to the CCTV scheme. This means that the control room really only has to deal with perhaps only 2 incidents of significance per day (out of 16 hours worth of ‘person viewing time’, an effective incident rate of 1 every 8 hours (one for each person’s shift). In the context of a mass media, fast paced entertainment culture it is easy to see why this rate of action could be construed as rather boring. In this context, it is also easier to see why the role has been seen as low-status, and why operator recruitments exhibit a high-turn over. In terms of thrill and drama levels the day-to day experience is not as high-octane as the Battle of Britain, nor does the role have the social conspicuity of face-to-face policing or life-guarding. However, the incidents in July 2007 at Glasgow Airport for example, show that a modern control room anywhere in the UK may have to go on full emergency footing with zero notice.

When looking at staff engagement, it may be more profitable in terms of efficiency to have a wider, more culturally diverse, pool of operators working for shorter, more varied, shifts but with more of a time overlap. The reality of staffing issues means that in order to achieve full coverage, staff often have to work more than the regular 8-hour shifts, and take overtime pay. Not all systems in the provinces have achieved 24-hour coverage, nor have they achieved two-operator coverage. Inevitably the demographic profile of the operator pool is restricted. A wide cultural pool of staff effectively immunises the groups against the danger of inappropriate stereotypes that can arise from 'in-group' processing effects in narrow social groups (e.g., Brown, 1996)[3]. Having a large, broad-based trained staff pool would make the team less vulnerable to depletions due to leaving, as more individuals would be available for cover. Staggered shift change-overs would help to ensure hand over of knowledge. To effect all of these changes, the decisions would have to be underpinned by a substantial and credible body of research informing policy, procedure and practice.

Simple analysis of actual performance statistics cannot form the sole basis for developing best practice. As a result of the perceptual phenomena we have reviewed, not all the incidents that should be tracked are detected and noted. To compound matters, the operators and evaluators will naturally not know what incidents and events they have missed; worse still the operators will still feel that they are performing better than they are – and probably better than their peers too (as we saw with the example of 'change blindness' blindness above from Levin *et al*. (2000)). The solution, as we have discussed, is to build a research programme of training and research using ecologically valid simulators as part as a wider agenda of continuing professional enhancement in policing. A professional status for operators (as has been begun with door supervisors in the UK) would be the first step in creating a culture of enhancing career prospects for operators. As the complexity of CCTV systems continues to evolve, the levels of expertise demanded of the operators is also continuously under upward pressure (e.g. camera control software problems are increasingly evident as systems move from simple analog to complex digital solutions (Hall, 2004)).

One other aspect of digital systems that tackles the staffing problems head on is of course the development of ‘smart systems’. The so-called ‘second generation’ surveillance systems (Surette, 2005) will apply computer vision monitoring software (e.g. Dee & Hogg, 2004; Fisher, Santos-Victor, and Crowley, 2005) to reduce activity on mundane operations and to trigger identification of potentially suspect behaviour. This should leave the operators free to have a more executive oversight of incoming material; but with the ability to drill down to the lowest levels of source material when the occasions demand. However, Surette (2005) notes that technology can result in cluttering up of the time available for the fulfilment of primary functions. In addition, it is noted that in order for such systems to be effective in the long term the detected behaviour must then be responded to. If the public become aware of a lack of response to independently observed crime then their faith in the overall system will be sorely tested. Automatic Number Plate Recognition (ANPR) already generates more ‘hits’ (unlicensed vehicles) than can be ‘actioned’, but this system is not really compromised by lack of immediate follow up since illegal cars are not obvious to the public. However, ‘bus lane’ violations are automatically detected by a CCTV system in Aberdeen but, due to lack of resources in follow up, the system (very conspicuously) has only resulted in a 10% conviction rate (Urquhart, 2005), thus weakening the perceived efficacy of the CCTV system. If violent crime or robbery is widely seen to occur within the sight of CCTV, but is not seen to be followed up swiftly, then faith in mass surveillance really will be challenged. CCTV seems to deter deliberate criminal activity (or at least displace it). However, emotionally charged crime such as street brawls still occur regularly under the noses of surveillance cameras (Williams and Johnstone, 2000; Walker, Kershaw and Nicholas, 2006). The lesson to take from these examples is that low-value or trivial data must be kept out of the system or it will impinge on the effectiveness of the system.

In addition to the volume of information in the system, the way that information is communicated about suspects is vital to ensure that the relevant information is transmitted and irrelevant or potentially confusing information is restricted. Despite all the work already done on eye-witness memory (e.g., MacLin, Zimmerman, Meissner, MacLin, Tredoux & Malpass, 2008), much remains to be learned about the appropriate methods to achieve the best way of reporting categories of descriptions such as face, height, weight, age, skin-colour (race), hair style, clothing, clothing-colour, for events as they continue to unfold. In post-event interviews, the ‘cognitive interview’ technique has shown how rich, vivid and accurate recall can be under ideal circumstances with a trained interviewer (Geiselman, Fisher, MacKinnon, Holland (1986). However, in the live pursuit context, there is no such luxury of time. Therefore the selection of the salient information is absolutely essential. Incorrect, or vague or misleading descriptions can result in misidentifications which have potentially disastrous consequences (e.g. IPCC, 2007).

It remains an empirical question as to what features observers should concentrate on when describing and relaying information about suspects: for example: gender, clothing and height etc.. Developing a robust standard descriptive terminology will be a vital first step forward in crime prevention, detection and arrest and prosecution. (e.g. to how to best describe structural features cheekbones, nose, hair style, clothing). This could and should be empirically determined. Such a methodology would alleviate the worst difficulties associated with the own-race-bias (see Meissner and Brigham, 2001 for a review) where inexperience in dealing with the structural nuances of 'unfamiliar-race' faces can lead to a loss of discriminative power. By generating a consistent, widely accepted, lexicon of descriptive terms it should be possible to reduce inter-observer variation in descriptions and identifications and thus minimise false-alarms and maximise correct detections.

Information, of course, flows in various ways from control room to individuals on the ground. The bandwidth of information systems has dramatically increased so that actual video footage can be streamed to mobile devices 'on the ground'. This has the benefit of removing the possibility for descriptions getting 'lost in translation' from image to phone or radio. Rather than simple 'mug shot' photographs, it is possible to provide multiple views of a face, or even moving head and shoulders shots, including full-face, ¾ and profile. So far, it is has not been shown that this additional information provides any substantial benefits for line-up judgments (Darling, Valentine, & Memon (2007). Because field work is typically very different to line-up judgments, additional research would be required to establish whether the additional time taken to transfer and then inspect multiple or moving views of a face would deliver real benefits in the field (presumably field agents would prefer to have the extra information). In the context of abstract data visualisation, most users prefer to see complex dimensions in a data set presentation (by adding colour, depth, motion etc.) rather than seeing simpler displays, but what is less clear is whether this preference actually enhances interpretative performance (e.g., Fischer, 2000). For example using 3-D depth from motion does not appear to help unusual data points 'emerge' from data sets, yet users may well assume that they would be easier to see under 3-D conditions (Shovman, Szymkowiak, Bown and Scott-Brown, 2008). The additional time taken to inspect multiple views (or even a rotating view of a face) may not be practical in the context of fast-developing incidents on the ground.

The use of colour in descriptions is particularly amenable to a rigorous research agenda focussed on establishing precisely when and where it should be included in surveillance and in reporting contexts. In the context of face recognition, Bruce *et al*., (1999) showed that rendering unfamiliar faces in colour as opposed to monochrome gave no benefit in subsequent recall performance. Likewise, Scott-Brown and Mann (2005) showed no colour benefit over monochrome for detection of suspicious behaviour. The reliability of colour as a tool in surveillance is almost universally assumed by the public (e.g. Davies and Thasen, 2000), yet video cameras do not accurately reproduce colour in all lighting contexts [4]. In conditions of poor light, these reproduction problems are particularly noticeable to the extent that some CCTV operators prefer to display images in monochrome even though they have colour systems (personal observations from interviews with practitioners conducted by the authors). As an evidence base in court, colour has obvious benefits for the purposes of identification. However, in the field and in ongoing surveillance and pursuit colour may potentially mislead the team if the equipment generates an illusion of colour specificity that is not reflected in the natural scene. In the context of multi agency pursuit and surveillance, as many as 1 in 6 of the team may have some form of anomalous colour vision (i.e. colour blindness, e.g. Blake and Sekuler, 2005) unless this is screened out at recruitment. Therefore, care must be taken not place unrealistic expectations on the precision of colour descriptions in surveillance context, particularly when lighting and reproduction systems can introduce large variations in perceived colour. A continued effort in Applied Psychology can tell us about the usefulness of colour information in face recognition, it can also reveal how much about structural information of the face we could and should use in encoding and retrieval of face identification information from memory.

Operation rooms are only as good as the staff employed in them. Vast quantities of data that are recorded in any 24-hour period require interpretation and decisions as to whether behaviour is normal or not. As we have discussed above, one of the classic heuristics that humans use in such a complex task is the formation of stereotypes to simplify the world around them (e.g., Brown, 1996). This may have negative effects when looking for suspects and having little time to scrutinise large volumes of data. Williams and Johnstone (2000) note that CCTV operators are liable to ascribe negative stereotypes to social ‘outgroups’ (e.g. ‘hoodies’, ‘youths’), and consequently single out these groups for surveillance out of proportion to the threat that they pose [5]. This requires control rooms to be properly managed by trained staff who have an overview position and thus are able to moderate operator overzealousness. In the long term, appropriate training based on social diversity can eliminate much of the negative effect of inappropriate stereotyping. Spotting the out of the ordinary needs expert knowledge of the way things should look and the way people should behave. Much of this can be predictable if the observers know normal routines and details intimately. Indeed, experienced operators claim to ‘get a gut feeling’ about certain individuals or groups who are safe or dangerous (Manchester and London CCTV Staff, Personal communication 2006, 2007). Incidentally, this chimes with observations made by experts in other fields of visual expertise (see Gladwell, 2005 for an engaging overview). Shift patterns in control rooms can be arranged to exploit this expertise. Operators can be trained to have detailed local knowledge with a combination of in-control-room training and on-the-street familiarisation via vehicle and via walkabout. This would include night-time training, because streets that operators may know very well from daytime experience may be radically different at evenings and weekends. Only by experiencing the sights and sounds of the target areas in person can operators have a true perspective of the area in its wider context when called upon to make real-time speeded decisions in rapidly emerging situations.

Given the increased reliance on multiple camera systems, the individual operators do not have time to follow up every suspicious hunch played out in front of them. Currently most systems only store a time-lapse version of events from cameras that aren't directly being observed on the operator PC monitor or on the 'video wall' of the control room. We suggest that a digital video 'marking' system could allow operators to flag up given camera views over time for subsequent (post-event) analysis if events do unfold in a more dramatic or unfortunate way. This would allow for full-frame full-motion storage of camera footage even if the operator then switches to other cameras for further searching. The ability to set a 'mindsight marker' (to use the terminology described by Rensink (2000) earlier) would be particularly useful in 'second-generation' CCTV systems (Surette, 2005). By storing digital 'markers' or 'flags' to events that do and do not escalate into full blown situations, it would be possible to retrospectively profile the 'sensitivity' (Green and Swets, 1966) of individual operators. The powerful statistical technique known as Signal Detection Theory assesses the proportion of 'Hits' to 'False alarms' (i.e. the ratio of correct detection versus 'cry wolf') has been seen to provide a powerful statistical tool for evaluating operator efficiency (Troscianko, Holmes, Stillman, Mirmehdi, Wright and Wilson, 2004).

Discussion

Modern surveillance technology is highly complex and powerful. However, this complexity is dwarfed by the complexity and power of the individual human visual and cognitive decision making systems. Surveillance related tasks are set of course in intra-individual (individual identification), intra-group (junior and senior officer interactions) and inter group contexts (relations between the police and other groups). These added layers of complexity expand the overall problem exponentially in modern society. As technology advances and society becomes ever-larger and complex (e.g., Moore, 1965), our need to understand and unravel the growing complexity of the human interface also grows. The biggest strength of the human operator is to make conscious decisions, and apply the role of context to narrow down the computational complexity present in the incoming information. This strength also contains the flip-side of selective attention – namely the potential for too narrow a focus of attention via over-focussing or via attentional-set – leading to change blindness in the worst cases. Much practical insight can be gained by studying the system at work in relevant, cognitively demanding, situations. This essential process is beginning to happen in vision science (e.g. Troscianko *et al*., 2004). Only in this way, can the human-system interface be optimised to maximise correct detections, and minimise false alarms and incorrect decisions.

Critical incident decision problems also exist for the operators and command staff who have detection and executive functions in a large CCTV control rooms. Modern city centre surveillance systems such as those installed in Manchester and London use state of the art equipment and highly skilled operators. However as technological capabilities improve over time, care must be taken to ensure that the keystone of the whole system – the human-machine interface – is also continuously improved to keep pace with hardware development. In particular developments must take account of the differential viewing characteristics of police, council and commercial users –each of which has different agendas or tasks (e.g. Cronin and

Reicher, 2006). Incidentally, in this context, the tendency for CCTV control rooms to be jointly run with council staff appears to be desirable on a number of levels (e.g. by broadening the range of stakeholders in a system and widening the institutional culture(s) within the control room environment).

We are arguing for an enhancement in the way that police utilise individual and group level identifications, such that police officers (and other individuals) at strategic, tactical and operational levels of command are made aware of the improved possibilities of correct versus incorrect identifications by officers utilising the range of technology that is available to identify suspects in both individual and group/crowd situations. This requires an understanding of the need for operational staff to be made aware of the relevant psychological processes, and how they affect the work environment. This holistic approach should ensure that designers, procurers, managers and day to day operators are fully conversant with the issues that may arise in relying on this technology in policing activity including: investigation, use of information/intelligence, decisions to arrest and prosecute, and presentation of evidence in subsequent court proceedings. This would provide the best opportunity for all the elements of the Criminal Justice System to work together to ensure that investigations are as seamless as possible.

This informed, scientific, approach to surveillance, detection and decision-making, should feed into the public understanding of these processes. Misconceptions about process should be challenged, illusions explained, and processes better understood. In this way, public acceptance of surveillance will be enhanced or (at least maintained), and errors reduced or eliminated. In spite of the proliferation of CCTV, academic interest in the topic has been politely described as ‘rather slight’ by Williams and Johnstone (2000). However, insights uncovered in the context of an experimental laboratory can have relevance to the decisions made by officers, support staff and others involved in policing both the daytime and night time economies. How these individual decisions are made, in the context of the groups that people work and operate in, will be a critical research area to investigate in the future. To be successful, the investigations should form part of a wide-ranging collaborative research agenda. Computer based surveillance simulators can give the experimental credibility required to convince the scientists whether policy, procedure and practice changes are measurably superior. If scientists are convinced, then they can try to convince the practitioners. Artificial simulators are an essential part of this process of quality enhancement because highly stretched policing authorities cannot afford to test a multitude of operational options by directly pitching ‘experimental trials’ straight into real operations rooms. There is a requirement to try and assess the benefits via simulations in the first instance. These environments have no negative consequences for incorrect outcomes and the tests will not jeopardise mission critical events.

A scientific approach to surveillance needs to incorporate reasoning and thought processes of the personnel throughout the organisation. This need has been most prominently advanced by scientists in the newly emerging field of ‘Visual Analytics’ (e.g., Thomas, & Cook, 2005). This discipline represents the convergence of cognitive sciences, mathematics and computer science in a concerted attempt to develop novel technological solutions to the ever-increasing volume and complexity of information streams. However much of the current research in this discipline is focussed on the development of new visualisation techniques based on exploiting the maximum power and complexity of modern computer graphics hardware and software largely for their own sake. A recent National Institutes of Health/National

Science Foundation (USA) report (Johnson *et al.*, 2006) points out, however, that this is often done at the expense of ensuring a sufficient grounding in basic research (e.g., psychophysics, perception and cognition) or at the expense of servicing a clear and present need (e.g. medical engineering, fluid dynamics, surveillance). The best visualisation techniques need not necessarily be the most technologically advanced; they need to be the most suited to the abilities of the user and to be appropriate and clearly evaluated as reliable. Although Surette (2005) has already documented the genesis of second generation CCTV systems that automatically detect suspect behaviour. We suggest that the target should be 'third generation' systems that dynamically inform the monitoring and evaluation of the full data stream of information impinging on control rooms: video, audio, voice data, digital data, operational communications and so on.

To make a visual analytic research agenda work, Police and related agencies must work as closely as possible to minimise the risk of important information/intelligence being lost in various policing information systems (as identified during the 9/11 Commission Report (e.g., Walker, 2004). At the same time, Police and related agencies must actively engage in research activities (e.g. UK: Scottish Institute for Policing Research, Home Office Scientific Development Branch, Surveillance, Evaluation, Research, Validation, and Exploitation (EPSRC Research Council Funded Network), US: Department of Homeland Security, The National Visualization and Analytics Center (NVAC™), National Institutes of Health, National Science Foundation).

In sum, we are arguing for a programme FOR research rather than OF research dedicated to the need to understand these complex interactions. This requires investigators not to simply follow existing programmes of research; rather to develop programme areas for research. For example topics for exploration could include: visual analytics; control room technology; decision making in structured groups; issues around accountability; issues relating to unfamiliar faces; performance under stress and fatigue, and so on. Future funding programmes should reflect these priorities and focus on uniting the outputs of different disciplines. Denzin (1988) makes the point that researchers should avoid being constrained by the methods they use when formulating their research questions. There can be a tendency/inclination for investigators only to measure what is easy to measure, or only to measure what they know how to measure (particularly when making the transition from the laboratory to the field). The halfway house from ‘lab’ to field is the immersive environment, it provides a very flexible extendible, inexhaustible method for training. In the same way the immersive environment permits data collection in a controlled manner (like the laboratory) but in more ecologically valid settings (like the real world). The quickest solution to avoiding the method trap posed by Denzin (1988) is to engage in multidisciplinary research (this builds capacity more quickly and with a larger scope than simply using a single investigator to ask all the questions). Multidisciplinary work is regularly used in vision science where neuroscience, behavioural science and psychophysics unite to triangulate their findings to reach new conclusions. To achieve such a programme FOR applied surveillance research, there needs to be better interaction between practitioners and academics – both by academics inviting practitioners into the laboratories and by police inviting researchers in to see the problems.

In addition to ongoing research, there is a need for dissemination in language appropriate for field practitioners, policy makers, managers and the general public. Currently most research is published in academic psychological journals with a limited readership – and is written in what can politely be described as a less than optimally accessible style for the non-specialist. Police and academic communications and collaborations should be seen as part of a wider agenda for the improved status of public understanding of science. Funding bodies already grade and evaluate research proposals with wider dissemination in mind, however they are in a position to engineer much closer collaborations by inviting or requiring collaborations as a condition of funding, or even as the basis of funding. The first obligation of the research community is the dissemination of contemporary research to practitioners in a format that is both readily accessible and readily applicable. To date, this is an area that is sadly seen as a subsidiary priority in research laboratories across campuses; (Gladwell, 2005 and Wiseman, 2004) are notable exceptions.

The key message for surveillance practitioners and policymakers is fundamentally about the nature of the human visual system. There is a preconception in the media, and the public in general, that the eye and brain act like a camera, and that human memory acts like a video recorder – slavishly recording the perceived events with 100% accuracy and in hi resolution format. The brain then dutifully evaluates the information incoming and provides error free analysis. Of course the reality is that the human brain's solution to the complexity of the environment is to use short-cuts, heuristics, and even stereotypes to simplify the decision making process (as so vividly described by Gladwell, (2005) who gives the process the name of 'thin-slicing'). Most of the time this works reasonably effectively but often in the modern world, our cognitive apparatus is not up to the job. The sooner we can fully document and understand the limitations of the human apparatus, the sooner we can develop better strategies for effective and efficient surveillance in the context of an overall policing strategy.

Whether the detection is made by humans or by machine, a greater quantification of the limits of human performance underpinned by a theoretically well founded understanding of the evolutionary context of violent behaviour (Buss, 1999; New, Cosmides and Tooby 2007; Scott-Brown and Cronin, 2007) can help operators and police in interpreting and understanding the events unfolding before them. The message is that we should not allow ourselves to be seduced by the technology. It is all too easy to assume that bigger, more-vivid, displays with more information will allow transmission of more information, but there is only so much that we can attend to. In conclusion an informed research based awareness of the consequences of attentional focus (e.g., attentional set, retrieval induced forgetting) the potential for misperception (e.g., change blindness, inattentional blindness, change blindness blindness) and the shortcuts used by our brains (e.g., stereotypes, thin-slicing) is the best defence against misdirection and complexity in the modern security and policing environment. Word Count [8540]

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Footnotes:

[1] [Engaging and entertaining examples of the flicker paradigm are available from Ron Rensink's website. http://www.psych.ubc.ca/~rensink/flicker/]

[2] [Some excellent and amusing examples of these experiments are available to view on line at Dan Simons website: http://viscog.beckman.uiuc.edu/djs_lab/demos.html]

[3] [The 'contact hypothesis' suggests that intergroup differences and conflict can be reduced by constructive contact with 'outgroup members' (Brown, 1996).]

[4] [This misplaced faith in colour is another example of a 'metacognitive error' just like the change blindness blindness error described by Levin, et al., (2000) earlier.]

[5] [The efficacy of these stereotypes can be self-reinforcing since they generate recordable actions and the 'misses' don't usually show up anywhere in crime statistics.]