Design Considerations in the Proliferation of Police Body-Worn Cameras

An ergonomics analysis can identify areas of improvement to ensure effective use of cameras and the information they provide.

By Joel Suss, Alexis Raushel, Adam Armijo, & Brian White

FEATURE AT A GLANCE:
More and more police departments are equipping their officers with body-worn cameras. To maximize the utility of body cams, designers have considered issues such as camera-mounting position, camera-mount stability, methods of activation, and data transfer methods. The human factors/ergonomics community can make important contributions to the design of body-worn cameras and identify and address issues that could arise from the introduction of new technologies (e.g., biometric identification and automatic detection of concealed weapons). Engaging with this ever-expanding technology will benefit law enforcement agencies and the communities they serve and protect.

KEYWORDS:
accountability, body cameras, body-worn cameras, camera-mounting position, criminal justice, law enforcement, police legitimacy, policing, procedural justice, product design, product development

Body-worn cameras are gaining considerable popularity with law enforcement agencies and increased attention from the public and media. "Body cams" are small wearable devices designed to capture an audiovisual record of police–citizen interactions. The recorded footage can then be used for investigatory and evidentiary purposes.

In this article, we begin by outlining reasons for the proliferation of body-worn cameras and provide a brief overview of existing research. Then we describe some usability considerations in the design of body-worn cameras. Finally, we review current developments and associated design issues. Our main goal is to spur the interest of human factors/ergonomics practitioners in this proliferating technology.

Body-worn cameras were first trialed in the United Kingdom in 2005. They have since been adopted by law enforcement agencies worldwide. In the United States, adoption of body-worn cameras has been driven, in part, by calls for increased police accountability following high-profile events, such as the shooting by a police officer of Michael Brown in Ferguson, Missouri. In that case, the officer was not equipped with a body-worn camera, and his account of events was subsequently disputed by eyewitnesses.

Body-worn cameras are intended to increase transparency between officers and the communities they serve. One way in which they contribute to this goal is by providing an objective record of events (i.e., one not subject to memory errors and biases). In fact, one of us (BW) has observed instances of citizens withdrawing complaints against officers after being informed that the incident in question was recorded by the officer's body-worn camera.

THE PROLIFERATION OF BODY-WORN CAMERAS

In the United States, support from the federal government has helped drive the proliferation of body-worn cameras. In May 2015, under President Obama, the Department of Justice's Office of Justice Programs announced $20 million in matching grants to support body-worn-camera implementation (Department of Justice, Office of Public Affairs, 2015). Seventy-three awards were made, covering the purchase of 21,000 body-worn cameras.

Vendors are also driving adoption. Axon, previously known as Taser International, is one of the biggest – if not the largest – supplier of body-worn cameras to U.S. law enforcement. In April 2017, Axon offered to provide every police officer in the United States with a body-worn camera for one year – for free (Axon, n.d.).

A recent market survey listed 66 body-worn camera products manufactured by 38 vendors (Hung, Babin, & Coberly, 2016). Each vendor attempts to distinguish itself through the array of features offered. This competition drives rapid technological development. The production of body-worn cameras is not currently regulated by standards or guidelines; vendors therefore develop their products based largely on perceived needs, customer demands, and technological possibilities.

Although the physical body-worn cameras are the most visible part of the system, the secure transmission, storage, and use of recorded footage are also important elements. In fact, the majority of revenue from sales of

body-worn cameras is associated with the ongoing data storage costs rather than the initial outlay for the cameras (Barbour, 2017).

Body-worn cameras are a popular topic in law enforcement circles. For example, the International Association of Chiefs of Police sponsored its first symposium on body-worn cameras at its 2016 conference. Additionally, the Force Science Institute, a for-profit company specializing in human performance issues in law enforcement, offers a training course addressing the use of body-worn camera footage in investigations and incident analysis, calling it "today's hottest policing topic" (Force Science Institute, 2017).

RELATED RESEARCH

Body-worn cameras have the potential to benefit both police and citizens. Research into the effects of body-worn cameras is growing in the fields of criminology and criminal justice. Two of the main expectations associated with the introduction of body-worn cameras are reductions in the number of (a) incidents in which officers used force against citizens and (b) complaints by citizens against officers. There is evidence supporting these expectations (e.g., Ariel, Farrar, & Sutherland, 2015; Jennings, Fridell, & Lynch, 2014; Ready & Young, 2015), but there are also contradictory findings: Ariel et al. (2016) found no evidence of improvements in these areas.

Despite the growing stream of body cam-research in criminology and criminal justice, very little research has evaluated the technology from a usability perspective. As with any new technology, there are human factors issues that need to be considered and addressed. In the next section, we review usability and human factors issues associated with body-worn cameras.

DESIGN CONSIDERATIONS

As with most products, the design of body-worn cameras is likely to have a significant impact on their adoption, usability, and acceptance. Therefore, it is important for both designers and procurers to consider key human factors issues – such as video quality, camera-mounting positions, camera activation, and data transfer – when designing and selecting body-worn cameras.

Video quality. Although initially it may seem obvious that video should be recorded at the highest possible quality and resolution, this issue has been debated for several reasons. One is cost related: Higher-resolution cameras are more expensive and generate larger files, which are more costly to store. Another is that in some respects, cameras can outperform the human eye. Cameras can record wider fields of view with greater clarity than the human eye can perceive, and cameras can enhance footage under low-light conditions. The main concern here is whether footage should depict what an officer could potentially see with his or her own eyes or an enhanced representation. An enhanced representation might allow police administrators, the public, and the legal system to better understand a recorded incident.

However, many stakeholders erroneously assume that the officer involved could perceive exactly what the camera showed (Geis & Blake, 2015). It is not difficult, then, to imagine someone saying, "But it is clear from the footage that the suspect was holding a cell phone, and not a gun. But the officer fired anyway. Therefore, the officer must be racist." For this reason, some vendors – albeit a minority – restrict their camera's horizontal field of view and do not enhance recording in low light. The majority of vendors, however, produce cameras that maximize field of view and visibility. Those vendors may consider creating an option to export a modified version of the video for public distribution (i.e., one that is consistent with the limits of the human visual system).

Camera-mounting position. Because body-worn cameras go where the officer goes, they sometimes replace, or supplement, fixed in-vehicle dashboard cameras. The camera-mounting position, therefore, is an important consideration for several reasons. Some body-worn cameras are designed – and their form factor allows them – to be mounted in only one way (e.g., on the chest). However, when a camera is mounted on an officer's chest, it is possible that its view while driving (e.g., during a vehicle pursuit) will be partially obscured by the steering wheel and dashboard.

Another issue with torso-mounted cameras is that they may not always capture what an officer is looking at. Consider, for example, times when an officer turns his or her head independent of his or her body or shields his or her body behind cover while keeping a suspect in view. Additionally, when an officer assumes a shooting position, his or her extended arms can obscure a torso-mounted camera's view.

Other cameras, with different form factors, allow users to choose between several mounting positions (e.g., cap, headband, glasses, collar, epaulette). One common mounting location is on the arms of specially designed protective glasses, using magnets built into the camera and the glasses. The glasses provide a good mount for the camera as well as eye protection, with a choice of tinted or clear lenses. However, tinted lenses can present a problem when officers transition from bright (e.g., outdoor) to low-light (e.g., indoor) locations; they often remove their glasses and rest them on their head. The result is that the camera now points skyward, failing to capture the officer's perspective. One way that officers can deal with this issue is to install an additional camera mount in a secondary location (e.g., collar) and to move the camera if the situation permits (e.g., before entering an indoor location).

Other considerations relate to tactical situations. For example, an officer's handedness and eye dominance can influence which side of the body will be exposed when taking cover. We have viewed footage of an incident in which a right-handed/right-eye-dominant officer took cover behind a tree while aiming a patrol rifle. His body-worn camera was mounted on the left arm of his sunglasses. As a result, the

camera recorded close-up footage of the tree and not the agitated suspect, who was holding a weapon. Furthermore, adopting certain shooting positions can change a camera's positioning, rendering it ineffective. The extent to which this occurs will depend on the individual officer and the camera-mounting position.

Camera-mount stability. Many body-worn cameras are mounted to an officer's clothing via a clip or mounting bracket. Under some circumstances (e.g., physical scuffles), cameras can get knocked out of alignment or fall off their mount completely. We have also seen collar- and epaulette-mounted cameras dislodged from their mount when the officer fires a shoulder-fired weapon (e.g., rifle, shotgun). At least one vendor offers a camera that mounts in a special pouch inside an officer's shirt; such a camera should be more difficult to dislodge.

Cabling. Although some body-worn cameras are a single unit that comprises the camera, power source, and recording media, other systems use a smaller camera that can be mounted in a variety of locations and is connected to its chest- or belt-mounted power source via a cable. It is possible for the cable from the camera to the power source to become disconnected (e.g., during a physical scuffle), which would render the camera useless.

Vendors have since designed jacks that incorporate a plug retention device, which prevents the cable from being easily pulled out. Nonetheless, officers must still consider how they route the cable to minimize the chance that it will catch on something (e.g., a tree branch). We have also heard some officers express concern that the cable could be used against them, like a garrote, during a fight.

Camera activation. Many body-worn cameras are designed to be activated manually (e.g., with a double press of a button). A concern of civil liberties groups is that officers will intentionally fail to activate their body-worn camera if they are about to behave inappropriately. For this reason, some groups have advocated for continuous recording (Schumm, 2017).

Although some body-worn cameras can record and store up to 8 hr of footage (i.e., close to the duration of a typical shift), some have argued that it is unnecessary to record everything an officer does. Is it really necessary, and fair, to record the officer using the restroom, eating, and completing paperwork? Even if we assume that officers largely behave appropriately, it is still possible that they might legitimately forget to activate their body-worn camera (e.g., in stressful situations).

In light of these issues, several methods of automatic activation have been developed. These include activation via (a) physiological measures, such as speech recognition (e.g., verbal commands) and increased heart rate; (b) kinematics, such as the officer running or being involved in a physical struggle, using accelerometers built into the camera; (c) in-vehicle sensors, triggered when a police vehicle's light bar/siren is activated or when the officer's shotgun is removed from its in-vehicle mount; (d) holster sensors that activate the camera when the weapon is drawn; (e) geographical location, using predefined zones of interest (e.g., high-crime areas); (f) central dispatch, remotely; and (g) Bluetooth (e.g., when another officer's camera is activated close by).

Camera visibility. Should body-worn cameras be worn overtly or more discreetly? Most cameras are designed to be worn overtly. One argument for overt wear is that citizens will see the camera, recognize they are being recorded, and temper their behavior. At least one vendor has designed a camera with a built-in, forward-facing display, so that it is obvious to citizens that they are being recorded. However, one argument against such overt wear is that citizens may feel that they are being unduly surveilled and might therefore behave differently than they would have otherwise.

Data transfer. Many cameras record to internal memory (e.g., integrated flash memory). At the end of their shift, officers return to their base and use a specially designed charging/docking station to securely upload footage to remote secure servers. However, it can be inconvenient to have to wait until the end of a shift to upload video or return to a specific location. It also delays supervisors from viewing footage of an incident. In response, some vendors offer systems that will stream footage to dispatch centers and storage servers in real time.

Interpretability of footage. Body-worn camera footage can be difficult to interpret (Williams, Thomas, Jacoby, & Cave, 2016). A single view of any incident may not tell the whole story. When publicly disseminating body-worn camera footage, some law enforcement agencies have taken to providing step-by-step commentary of camera footage. This should contribute to minimizing misinterpretations by the media and public.

FUTURE CONSIDERATIONS

Body-worn camera technology is developing at a rapid pace. In this section we consider recent developments from an ergonomics perspective.

Biometric identification. There is the potential to scan body-worn camera footage in real time and identify individuals based on face, iris, voice, or gait recognition. At least nine vendors offer facial recognition as a feature. The body-worn camera would be linked to a biometric database (e.g., FBI Next Generation Identification database), and the officer would receive, in real time, information about the citizen he or she is interacting with (e.g., name, age, arrest history, convictions). The promise of such technology is that it could avert tragic situations, such as the shooting of Philando Castile in Minnesota, by advising the officer that a citizen has, for example, a gun license but no history of violence (Kofman, 2017).

However, several ergonomics issues spring to mind. Would the biometric identification function reliably under a range of environmental conditions (e.g., indoors/outdoors, bright sun and low light, crowded areas)? How close would the officer need to be to a citizen for a match to be made? Would the biometric information be presented automatically upon a match being made (e.g., via a head-up display), or would officers be prompted to access the information? How could the information be presented to the officer to minimize distraction? Will officers be presented with information about the degree of match certainty, and will they be trained to interpret this information appropriately? Would automated recognition be active at all times, potentially bombarding the officer with information? Might officers come to rely on biometric identification as an indicator of threat, instead of maintaining their ability to pick up on subtle behavioral cues that might signal impending danger? Similar issues apply to another feature offered by at least two vendors: the ability to automatically detect concealed weapons.

Live streaming of footage. Instead of having to wait for officers to finish their shift and return to base in order to upload and view footage, some vendors are now promoting live-streaming systems. Such systems would enable dispatchers and police commanders to view live footage from the confines of fixed or mobile command posts. Such systems claim to enhance a commander's situation awareness.

However, the implementation of live-streaming systems does not take into account the cognitive burden of monitoring multiple video feeds simultaneously or the commander's ability to integrate all of the information. Similar to the issue of supervisory control when deploying multiple unmanned aerial systems (e.g., Goodrich & Cummings, 2015), law enforcement may benefit from research into the span of a commander's supervisory control.

Training. Body-worn camera footage can serve as a rich source of training information (Richards, Roberts, Britton, & Roberts, 2017). For most agencies, however, manually scanning all recorded footage is impossible because of the sheer amount of footage recorded on a daily basis. Some companies are working on applications that employ computer vision and automated intelligence to analyze and categorize body-worn camera footage. However, the ability of those applications to identify incidents that have training value is not yet clear. Even if it is possible to identify incidents with training value, there still exists the challenge – with respect to subject-matter knowledge and the time required – of creating engaging and effective instructional material (Corso et al., 2015).

RECENT AND ONGOING RESEARCH

We found only one paper that focused on ergonomics issues related to body-worn cameras. Ilori, Li, Mahesh, and Craig (2017) investigated how the positioning of body-worn cameras and speaker microphones affected performance during a simulated foot pursuit. Participants reported lower workload when the two devices were combined into one unit and mounted on the chest, compared with when the combined unit was mounted on the shoulder or when the camera was mounted on the chest and the speaker microphone was mounted on the shoulder.

Figure 1. A female officer wearing nine body cameras for a study that compared target visibility across camera-mounting positions. From the top of the figure, the officer is wearing cameras mounted on the hat (left/right), Oakley protective glasses (left/right), collar (left/right), epaulettes (left/right), and chest (center, below visible button and integrated with power supply). Only five power supplies (i.e., rectangular black boxes on chest/stomach) are visible; the other four power supplies are mounted on the officer's back.

In collaboration with the Wichita (Kansas) Police Department, our lab is investigating the advantages and disadvantages of different camera-mounting positions. We equipped officers of varying heights, weights, and body types with up to nine Taser Axon Flex body-worn cameras (see Figure 1). Three officers each completed 35 live-fire drills, in which they fired at a static paper target using a handgun, patrol rifle, and shotgun. We varied the officers' starting position (e.g., facing the target, turned away from the target), shooting stance (i.e., Weaver vs. isosceles), and grip (e.g., one or two handed). Four officers also engaged in live role-player scenarios (e.g., domestic disputes, ground fighting, traffic stops, and vehicle/foot pursuits).

We have begun to analyze the video footage from the live-fire drills. Each camera recorded a single video file that captured all of the participants' live-fire drills. After identifying the start/end times for each drill in each video, we sync the videos for each drill using video-editing software. Then for each drill, every frame of video from each camera – at 30 frames per second – is coded with respect to the visibility of the target (i.e., fully visible, partially obscured, or completely obscured).

Using these data, we calculate the proportion of each drill that the target was fully visible, partially visible, and completely

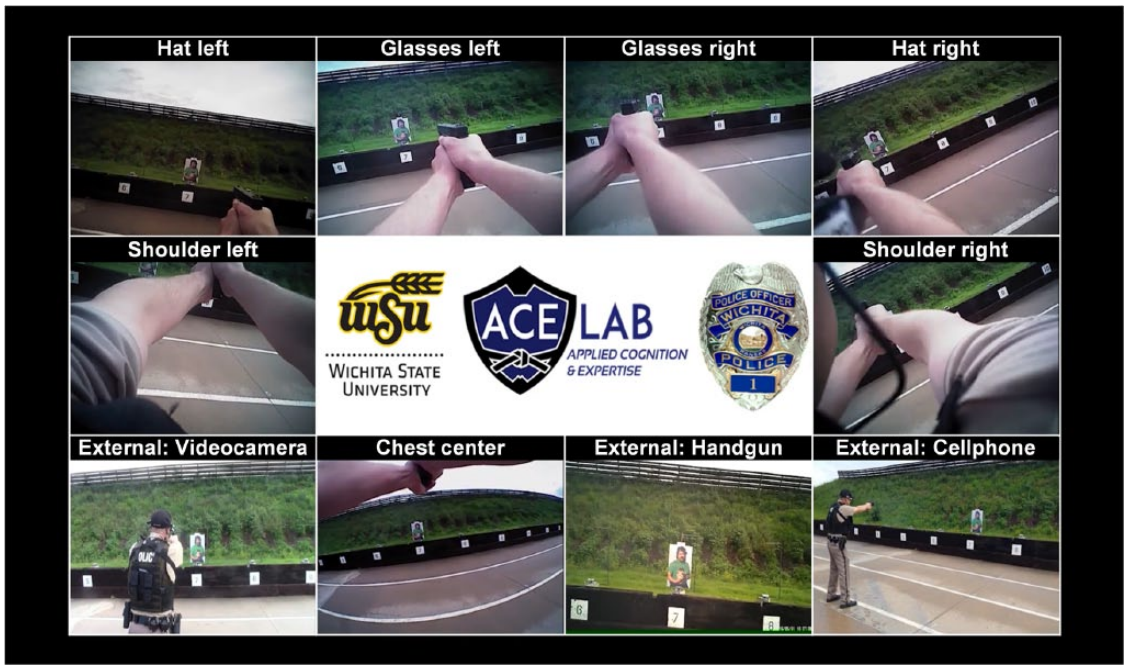

Figure 2. Sample video frame from a live-fire handgun shooting drill, in which a male officer fired at a static paper target of a male suspect holding a child hostage. The multiplexed view facilitates comparison of seven body-worn-camera mounting positions. It is clear – at least at this specific point in the shooting drill – that the two shoulder-mounted cameras do not offer clear views of the target. Three external perspectives are provided for additional comparison (bottom row: video camera, handgun, cell phone).

obscured. We plan to calculate overall proportions of target visibility for each camera-mounting position by averaging across drills, weapon types, and officers. We will also consider how target visibility is affected by the phase of the drill (i.e., drawing/aiming, firing, holstering). To reach conclusions about which camera-mounting positions afford the most complete view of the target, we will compare mounting positions on the head with those on the torso and those on the left side of the body with those on the right (see Figure 2). We anticipate that it will take a total of 8 months for our team of dedicated researcher assistants to complete the painstaking process of syncing, coding, and analyzing the live-fire videos.

Initial findings. Based on the work completed to date, camera-mounting positions on the head (e.g., glasses, baseball cap) appear to provide a more complete view of the target than those mounted on the torso (e.g., collar, epaulette). It appears that the torso-mounted cameras are less stable than those mounted on the head; their alignment changes as an officer adopts a shooting stance (e.g., raises and extends arms). An officer's arms and hands also appear to obscure the target more for torso- than for head-mounted cameras.

This finding suggests the need for redesigning some of the camera-mounting options as well as making officers aware of the advantages and disadvantages of various camera-mounting positions. We plan to make videos of the live-fire shooting drills publicly available so that police departments and individual officers can evaluate the footage themselves.

CONCLUSION

Although body-worn cameras are attracting the interest of the public, media, and academics in the fields of criminology and criminal justice, usability issues have received relatively little attention. We are finding that the ergonomics approach we are taking will benefit law enforcement by generating scientific evidence that can be incorporated into guidelines for the use and deployment of body-worn cameras. Our work has also drawn interest from experts working in the field of forensic video analysis: Having multiple perspectives of a scenario can be useful for showing juries that a single body-worn camera – with its limited view – may not be able to capture all of the important contextual information during an incident.

Finally, our video data can serve as training stimuli for artificial intelligence systems that are being developed to automatically analyze, categorize, and redact body-worn camera footage. Further work related to the design, use, and interpretability of body-worn cameras would benefit both law enforcement agencies and the communities they serve.

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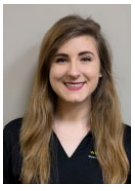

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