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The eyes have it! Functional field of view differences between visual search behavior and body-worn camera during a use of force response in active-duty police officers

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ABSTRACT

Although officer body-worn cameras (BWCs) have improved transparency of police interactions within the community, BWCs have a limited field of view, are subject to bias, and do not account for the factors that influence rapid decision-making by officers, including their visual attentional control and perceptual processes. The purpose of this study was to investigate the camera perspective of six critical incidents and position data from BWC compared to eye tracking and head movement data in a use-of-force scenario from 44 active-duty police officers. The analysis of gyroscope and accelerometer data demonstrated low correlations between eye cameras and BWC position data. Officers attended 80.5% of all critical incidents, whereas BWC view captured only 66.2%, especially missing key events (<48%). BCW footage did not account for the visual information and the behaviors of the suspect, potential threats, and bystanders who influence the officers' decision-making during the use of force encounters.

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KEYWORDS
Body-worn cameras; attention; gaze behavior; use of force

Officer body-worn cameras (BWCs) are often touted as a key to police reform by providing documentation of police interactions with the community and accountability during use of force encounters. BWCs have appeared to improve transparency. However, BWC footage is far from perfect and subject to interpretation. Recent work has demonstrated that viewers of BWC footage provide varied conclusions and opinions that are influenced by preexisting attitudes toward police and police behavior (Granot et al., 2014; Kahan et al., 2008). Irrespectively, BWCs are often used in the court system, by the general public, and by law enforcement authorities to evaluate police encounters.

Several works have shown that viewers will have different interpretations of events depending on the limited field of view of the camera and the biases of the viewer. In addition, body cam and dash cam footage will draw different conclusions from viewers (Turner et al., 2019) as BWCs may fail to capture the entire interaction of officers and the reaction of civilians or assailants. Much of the research to date has examined the viewer of the video footage and their interpretation of the events. For example, Ware et al. (2008) determined that bias could be formed by directing the viewer's attention to the suspect. Conversely, Sternisko et al. (2017) instructed participants to give the officer and civilian equal consideration and attention, reducing bias in legal decision judgments. Similarly, Jones et al. (2019) also concluded that body cam footage tended to result in bias about the officers' actions and intent; however, when body

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cam footage was coupled with a third-person view, camera bias was reduced in some circumstances. A recent review by Lum et al. (2019) noted that BWCs did not lead to a reduction in the use of force encounters by officers, and the anticipated effect of BWCs was overestimated. Contradictively, White and Malm (2020) explored the use of BWCs and found a potential benefit for BWCs to reduce use of force, reduce citizen complaints, and reduce injuries and fatalities, however, these authors also noted the need for more rigorous evidence on the use of BWCs to improve police practice.

BWCs are limited to the perspective of the officers' body and have a limited and fixed field of view of the behaviors of the suspects. They also do not account for the perceptual, cognitive, and affective processes of the officers. Officers are often required to make rapid tactical decisions based on their ability to recognize critical visual information and evaluate threats. The officer relies on their perceptual and cognitive skills to assess the situation, which is often novel, ever-changing, and involves time pressure (Andersen & Gustafsberg, 2016; Cohen et al., 1998). Formal evaluations, post-incident, may not consider these issues as the officers need to formulate efficient and proper tactical decisions based on the visual and behavioral information of the scene, which at the time was not available for introspection.

Visual scan behavior is primarily based on pattern recognition gained through training, experience, and through the development of tacit knowledge (Murray & Janelle, 2003). This skill development represents a selective attentional mechanism through which the officer will filter complex sensory stimuli to evaluate potential threats and maintain situational awareness. Knowing where and when to look is crucial for successful police performance, as these officers must be able to identify the most information-rich areas of the environment. Their reliance on visual attentional control allows for significantly more degrees of freedom (through eye and head movement) than through a chest-mounted BWC. In addition, BWC has other restrictions, including issues surrounding frames per second, field of view (FOV), and degrees of freedom. Although manufacturers have claimed FOV to be between 120 and 170 degrees, a recent test of BWC has shown the actual field of view to be less (72–114; Espenant, et al., 2015), and the BWC shows the orientation of the trunk but does not reflect the movement of the head and eyes. The head has three degrees of freedom: yaw, pitch, and roll, and eyes with head movements at any point can have a FOV larger than 160°. Beyond FOV, vision and decision-making are reliant on training and experience.

To this end, several works have demonstrated the visual search characteristics of skilled or elite officers used during simulated potential use of force scenarios (e.g., Murray et al., 2023; Nieuwenhuys & Oudejans, 2011; Vickers & Lewinski, 2012) in which officers engage in tactical decision-making by directing visual attention to critical relevant information. For example, Vickers and Lewinski (2012) examined the performance and visual scan differences between elite officers with extensive experience and training in firearms incidents and rookie officers during a potentially lethal encounter. In this scenario, the officers had to decide if the person was a threat by determining if an item drawn from their waistband was a handgun or a cell phone. If it were a handgun, the officer would deploy their firearm; however, it was expected that if it were a cellphone the officer would not deploy their firearm. Specifically, they found that elite officers had more accurate shooting, longer quiet eye duration on the cue (i.e., assailant's weapon/cellphone), and had an increased number of fixations on the assailant's weapon and preattack actions with their limbs and hands. In addition, Murray et al. (2023), through a use of force scenario, examined the visual scan rates and performance metrics of officers with varying amounts of tactical training. The authors found officers with better tactical training had reduced visual scan rates, were able to identify the assailant faster, had longer fixation durations on the suspect, and returned fire 85% of the time. Officers with less prior tactical training had higher scan rates with shorter fixation durations on important, relevant cues. In addition, these officers spent less time directing their visual attention to the relevant behavior of the assailant.

Overall, BWC footage cannot account for the selective attention processes and other factors that influence police decision-making during the use of force encounters. We sought to examine the camera perspective of police body cam footage compared to the eye fixations and head movements of the officer during the same scenario. It was expected that BWC footage would have a limited view of outcomes and would not account for the visual search patterns and head movements of the officer that lead to outcomes and better scenario performance during a use of force incident.

Method

Participants

Forty-four active-duty police officers (M age = 32.86 ± 7.2 years) with experience ranging between 7 weeks and 23 years (Mean = 7.05 ± 6.16 years) participated in the study.

Procedure

Upon arrival, participants completed the informed consent forms and were explained the purpose of the study. Next, participants were asked to wear standard training gear and outfitted with an eye tracker and GoPro. The participants were asked to complete a use of force scenario. Each scenario included two police officer participants, and four additional pre-scripted police trainers (e.g., actors). During this scenario, two officers were participants and were evaluated within each trial. The scenario ran for approximately 15 min. Of the four actors, one acted in the capacity of an off-duty patrol officer who was involved in a crash, one was a passenger in the assailant's car, one was the driver (assailant) who caused the crash and later attacked the officers, and one was another motorist who stopped to assist the passenger in the assailant's car. The participants were asked to respond as their training and police experience dictated. They aimed to control the agitated driver and resolve the conflict at the crash scene. While both officers (study participants) attempted de-escalation of the situation and to calm the hostile driver, the assailant became increasingly agitated and eventually acquired and discharged a firearm at the motorist and/or the officers. All participated in the scenario at the same point and all actors began the scenario at the same point. In addition, there was little variation in the behavior of the actors between scenarios (Horn et al., 2023). The study participants were allowed to react as their training dictated and respond appropriately by returning fire or taking cover.

Measures

Eye movements were tracked using two infrared eye trackers: Tobii 3 Eye Tracking Glasses (50 hz; Stockholm, Sweden) and Pupil-Labs Invisible eye tracking glasses (200 hz; Berlin, Germany). The Tobii 3 has an accuracy of .6 degrees of visual angle, and the Pupil Invisible accuracy is .5 degrees of visual angle. The video was obtained through the eye tracking glasses, giving a point of view (P.O.V.) of the officers, the body cameras on the officers, which was a mounted Hero8 GoPro (San Mateo, CA, USA) on the officer's chest. The Hero8 GoPro field of view in the wide mode of 133 degrees in the digital setting.

Both the eye trackers and the GoPro have Inertial Measurement Units (IMUs). X, Y, Z gyroscope and position data were extracted from the eye trackers and the GoPro body cameras. In addition, all data were time-synchronized using an audio signal of 48 KHz. The gyroscope data from the eye trackers provided head motion in addition to visual scan data. Likewise, the body cam gyroscope data provided the position of the body and the relative direction of the body camera. The gyroscope measures angular velocity at three axes, pitch (x-axis), roll (y-axis) and yaw (z-axis). Acceleration represents velocity changes in the x, y, and z directions. The videos from both the body cam and the eye tracking point of view (P.O.V.) were examined for behavioral outcomes such as where the officers were visually attending, the type and speed of their responses to the changing dynamics in the scenario, how quickly the situation was resolved and then were used to compare these behaviors to the officers' questionnaire responses.

All data were time-synced and extracted from the start of the scenario to the end, which concluded with the use of force (see Figure 1). Critical incidents were predetermined and built into the scenario. Then, two independent raters also evaluated critical incidents. Each rater would count critical incidents from the body camera and from eye fixation locations from the eye/scene camera. A critical incident for the eye camera would only be counted if the officer fixated (held a gaze position of 100 ms or longer) on the critical incident. iMotions software was used for post-processing by automatically layered fixation times on video. The critical incidents included a woman exiting the truck (1), first bat strike of the truck (2), bat drop (3), witness throwing a glass bottle (4), suspect retrieves weapon (5), and suspect fires weapon (6). Both views were scored, and a total incident score was created for each scenario/police view. The independent raters had a high inter-rater agreement ($r_{WG} = .95$).

Data analysis

The eye tracking data included the x and y gaze points, acceleration data from eye movements and from eye tracker glasses and the x, y, z gyroscope data from eye tracker glasses. Similarly, acceleration data and the x, y, z gyroscope and accelerometer data were extracted from body cam GoPro cameras. All data were visually scanned, and if any unexpected outliers or bad data occurred, it was removed.

Correlation Coefficient (CC) and Root Mean Square Error (RMSE) were used to estimate the consistency of the comparable measurements (e.g., gyroscope coordinates between eye tracker glasses and GoPro) and the amount of travel from zero for the gyroscope data in the x, y, and z directions. A larger error score represents more movement from the center point of the gyroscope (i.e., zero). The differences in the BWC view and Eye gaze view were analyzed using JMP PRO 14.0 (SAS Institute; Cary, NC). Total hit and misses were examined by percentages of fixated/not fixated vs captured/not captured and not data. Furthermore, a repeated measures MANOVA for the critical incidents including woman exiting the truck (1), 1st bat strike of the truck (2), bat drop (3), witness throwing a glass bottle (4), suspect retrieves weapon (5), and suspect fires weapon (6). Follow-up repeated measures ANOVA for each incident was conducted.

Results

Correlation coefficients were computed between gyroscope coordinates and accelerometer (Accel) data between eye tracker glasses and GoPro. The results of the correlational analyses presented in Table 1 show that none of the gyroscope comparisons were statistically significant; however, the accelerometer data was significantly correlated with the highest in the z-direction.

Generally, 80.5% of all critical incidents were recorded for eye data, whereas only 66.2% of the critical incidents were captured by the BWC (see Figure 2). In addition, the MANOVA results for Critical Incident Percentage demonstrated a significant effect for Camera Wilks' Lambda = .535, $F(6, 29) = 4.196$, $p < .01$. The follow-up ANOVA results demonstrated a significant main effect for woman exiting the truck ($p < .01$, $\eta_p^2 = 0.156$), 1st bat hit of the truck ($p < .01$, $\eta_p^2 = 0.138$), bat drop ($p < .01$, $\eta_p^2 = 0.164$), suspect retrieves weapon ($p < .001$, $\eta_p^2 = 0.210$), and suspects fires weapon ($p < .001$, $\eta_p^2 = 0.294$; see Figure 3).

Figure 1. Synchronized body cam footage and eye camera footage.

Table 1. Root Mean Square Error and correlations between Eye Tracker glasses and GoPro data.

Parameters	RMSE Eye	RMSE BWC	(p-value)	CC (r-value)
Gyro left-right (X-direction)	49.68 ± 7.86	37.49 ± 5.54	0.546	0.11
Gyro Up-down (Y-direction	21.16 ± 5.76	13.88 ± 4.52	0.378	0.16
Gyro fore-aft (Z-direction)	28.54 ± 2.70	37.49 ± 5.54	0.426	0.06
Accel X-direction			>0.05	0.42
Accel Y-direction			>0.05	0.33
Accel Z-direction			>0.05	0.46

Discussion

As expected, the BWC demonstrated limited perspective and missed critical incidents at least 33% of the time. In addition, there was considerably more head movement as officers scanned the environment and identified behavioral cues from threats and potential threats. While the BWC captured 66% of the critical incidents, the BWC effectively missed vital pieces of information, especially the two critical incidents that influenced police response, including 'suspect retrieves weapon' (74% vs 48%) and 'suspect fires weapon' first (80% vs 45%). In addition, the BWC does not account for the officer's ability to recognize patterns of behavior by scanning the environment and generating plausible responses given the current circumstances. The RMSE and correlation data from the gyroscope also demonstrated considerable head movements compared to body movements and indicated the reduced field of view from BWC data. There were moderate correlations of the accelerometry data. This is likely due to movement of the body and the head at the same rate throughout the scenario.

Visual scan behavior is primarily based on pattern recognition gained through training, experience, and through the development of tacit knowledge. As was noted by Nieuwenhuys and Oudejans (2011), Murray et al. (2023), Horn et al. (2023), and Vickers and Lewinski (2012), skilled or elite officers engage in tactical decision-making based on locating critically relevant information. The officer will engage in pattern recognition to generate plausible responses and an appropriate course of action. In addition, officers who have additional tactical training will adopt a more efficient course of action as they consider the possible outcomes (Murray et al., 2023). As such, much visual focus is task dependent, which drives attentional processes based on the gaze location of the eyes. The view for both eye tracking glasses and video captured by BWC was different for each

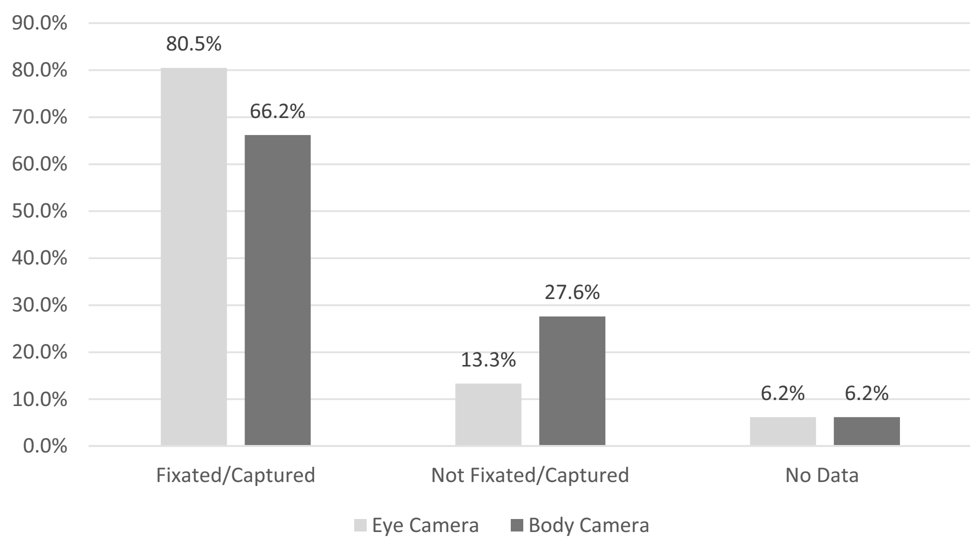

Figure 2. Total miss and hit rates by eye camera (fixations) and BWC (captured).

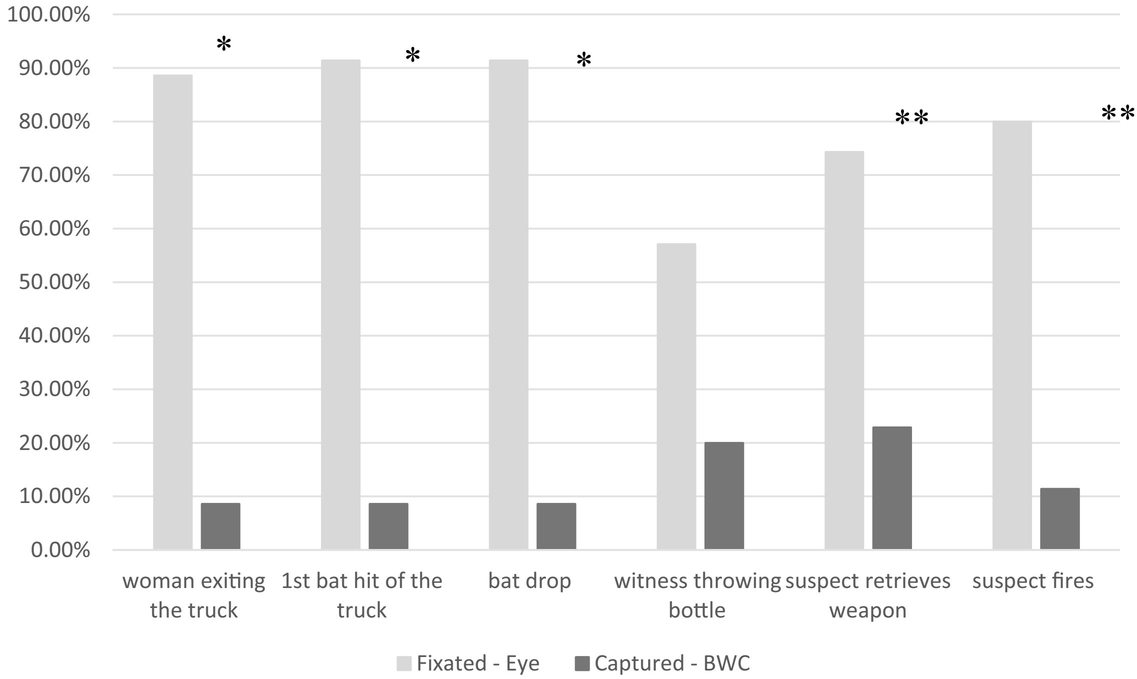

Figure 3. Percentage difference of BWC footage and eye fixations; *$p < .01$; **$p < .001$.

officer as they were allowed to proceed as their training and decision-making dictated. Initially, all officers entered the scenario at the same location and at the same starting point to mitigate the bias of one measure over the other and reduce a potential limitation of the study. It is also possible that a scenario could be designed in which elements could occur outside the view of the BWC; however, within our manipulation, the critical incidents at least had the potential to be always in the view of the BWC and the gaze of the officer.

Evaluation of BWC does not account for the visual search strategies engaged in by a police officer, and as such, viewers of BWC footage are reliant on opinions based largely on their preexisting attitudes toward police and police behavior (Granot et al., 2014; Kahan et al., 2008). Consequently, viewing from the eye camera likely would draw different conclusions about police behavior, similar to the work of Turner et al. (2019), in which interpretations of an officer's intentions differed between body cam and dash cam footage. This work is an important consideration for police, especially in cases involving BWC footage. BWC footage has value in reviewing police incidents; however, relying solely on this information can lead to faulty conclusions or missing details (White & Malm, 2020). As such, it is essential for law enforcement agencies to convey the limitations of BWC footage and during press conferences, the police chief or law enforcement representative should provide context of footage as well as limitations to the interpretation of BWC video. The reporting systems should account for the selective attention processes and other factors that influence police decision-making during the use of force encounters. Furthermore, camera systems can be embedded into standard-type eyewear. Although these may not include eye-tracking, these would give a similar POV as the officer.

In sum, we sought to examine the camera perspective in police BCW footage compared to the eye fixation and head movements of the officer during the same scenario. The BCW footage did not account for the selective attention processes of the officers in this scenario, as well as consideration of the behaviors of the suspect, potential threats, and bystanders who influence the officers' decision-making during the use of force encounters.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Notes on contributors

Nicholas P. Murray is a Professor in the Department of Kinesiology at East Carolina University. Dr Murray has authored over 40 publications and has spent his career examining visual and motor factors that influence human performance in dynamic environments. This includes research and publications concerning cognitive motor control, visual behavior, and motor dysfunction. His primary research interest is to determine antecedents and consequences of an individual's ability to function in dynamic situations based on physiological changes that can either facilitate or debilitate performance. He has extensive expertise in a variety of physiological and behavioral measurements including eye movement measurement; muscle activity; neuroimaging (electroencephalogram); biometrics, and heart rate variability. His recent work includes factors that influence visual expertise in officers when they encounter a threat or potential threat and the role of physiological arousal on visual search during a high stress, high threat, and use of force scenarios.

William Lewinski is a leading behavioral scientist whose work has focused on the intensive study of human dynamics involved in high stress, life-threatening encounters. He has a Ph.D. in Police Psychology and is a professor emeritus of Law Enforcement at Minnesota State University, Mankato, where he taught for more than 28 years, was an L.E. Program Director and also chair of the Department of Government. Dr. Lewinski's research has impacted law enforcement officers and agencies worldwide and has revolutionized the way force investigations and training are conducted. He is a popular presenter in the law enforcement industry and has appeared before scores of groups world-wide, ranging internationally from New Scotland Yard, the Royal Canadian Mounted Police, and the International Association of Chiefs of Police to the British House of Commons and House of Lords, as well as Obama's President's Task Force on twenty-first Century Policing. He has presented to local, state, and national departments throughout North America and the United Kingdom, including twice by invitation as a keynote speaker to international medical conferences in the U.K.

Craig Allen is a 27-year veteran of law enforcement and is currently a Commander with the Hillsboro Police Department in Oregon. He also serves as the Training Coordinator with the Force Science Institute, overseeing training programs and as an instructor within the Certification Course. In 2015, Allen received the prestigious International Association of Law Enforcement Training Association (ILEETA) "Trainer of the Year" Award for his innovative approach to police training and scenario design incorporating fundamental human factors research. Craig is also responsible for research and development of his agency's high liability areas relating to force response and is a court-recognized expert on police use of force and tactics.

Gustavo Sandri Heidner is a biomechanist and motor control scholar. His work focuses on the diagnosis and treatment of mild traumatic brain injury (mTBI) and how mTBI affects balance, upper- and lower-body motor control, and decision-making capability. He is also interested in research areas such as the development of motor and visuomotor paradigms in virtual reality and the application of scientific principles and processes to determine the true nature of human behavior in high stress and deadly force encounters.

Michael W. Albin is currently the Chief of Police at the Bristol Police Department in Bristol, Indiana. He has been a certified training officer for over 21 years. He is a Firearms Instructor through the Indiana Law Enforcement Academy (ILEA) and the National Rifle Association (NRA). He holds certifications in crisis and hostage negations, fraud and white-collar crime investigations, computer and digital forensics, organized intellectual property theft investigator, and network and router interrogations. He is a member of the United States Secret Service (USSS) Chicago Field Office Cyber Fraud Task Force (CFTF). He is a homicide investigator trained through the Southern Police Institute and is a Force Science Analyst and Advanced Specialist with the Force Science Institute.

Robert Horn is an Associate Professor in motor behavior at Montclair State University in New Jersey, where he has been employed since 2003. Dr. Horn's research has focused on the visual control of action, tactical knowledge in sports, and more recently, the visual and tactical responses of police officers in stressful encounters. Dr. Horn has authored 25 research papers and book chapters, and his work has been cited more than 1100 times. His future research with the police aims to more clearly outline the cognitive and attentional challenges associated with law enforcement in stressful encounters, with a view to informing police training.

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