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Behaviour Sequence Analysis of Police Body-Worn Camera Footage

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Abstract
Law enforcement officers in the USA have one of the highest lethal force rates in the world. A shortcoming of previous research on the use of force is that officer-subject encounters are observed as static events, and not a complex escalation of behaviours. Behaviour sequence analysis can identify common pathways that show chains of behaviours occurring at a level greater than what was expected by chance. The current study used 40 body-worn camera videos of officer-subject interactions leading to either lethal or non-lethal outcomes. The current results show that officers are more likely to use lethal force in response to physical threats from subjects, and likewise, use non-lethal force in response to verbal threats. The outcomes of this research extend to law enforcement and public safety, to understand and potentially reduce use of force incidents, particularly lethal force. It also serves to highlight the dynamic and challenging nature of these interactions to aid in establishing a greater rapport between officers and the communities they serve.

Keywords Body-worn camera · Policing · Force · Aggression · Behaviour sequence analysis

Law enforcement officers in the United States of America (USA) are authorized to use force in any situations that present an immediate threat to the safety of themselves or the public (Alpert, 2015). Force is typically defined as any action that goes beyond routine policing procedures such as verbal orders, handcuffing, or patting down subjects (Alpert, 2015). Policing guidelines dictate that officers follow some type of force continuum, which encourages officers to use the minimal amount of force required for a situation, escalating the force only when appropriate for the circumstances (National Institute of Justice, 2009). Continuums of force generally range from officer presence and verbal orders up to lethal tactics (Garner & Maxwell, 1999). Throughout the USA, these lower levels of force are constant across all jurisdictions, as is the use of lethal force as a last resort (Garner & Maxwell, 1999). Variation is seen throughout the middle levels of force due to the availability of less-lethal tactics (e.g., hands on tactics or oleoresin capsicum (OC) spray) (Garner & Maxwell, 1999). There is a clear need to understand use of force procedures, using real-world information and examples to show the complexity of the situations, and potentially how to better train officers to react in them effectively and efficiently.

Under any circumstance, the use of force by a police officer must be necessary for establishing control over a situation and should be justified as reasonable in proportion to the severity of the threat (Prenzler, Porter, & Alpert, 2013). If force is used without reasonable cause, it is considered excessive force, which has been a major factor of social unrest for decades, particularly when lethal force is involved (Prenzler et al., 2013; Shane, Lawton, & Swenson, 2017). Due to the complexity of officer-subject encounters, it is difficult to determine how various levels of force along the force continuum can be scaled against different levels of threat (Garner, Schade, Hepburn, & Buchanan, 1995). This creates a problem for officers when they must provide a justification of force incidents and has been a major shortcoming when applying previous research practically to the use of force (Garner et al., 1995; Shane et al., 2017; White, 2002). Indeed, traditional statistical approaches may not give a clear, real-world dynamic overview of incidents, missing much of the complexity that occurs in these situations.

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Previous research on the use of force is typically statistically based, disregarding the complex and dynamic nature of officer-subject encounters, reducing the outcomes to isolated factors, and ignoring the escalating sequence of events (Shane et al., 2017; White, 2002). For example, Shane et al. (2017) identify variables that are potentially related to the outcome of lethal force, such as armed or fleeing subjects. These terms, however, can have vastly differing influences in a practical context, such as being armed with a stick compared to a gun, or fleeing on foot versus a vehicle. Additionally, White (2002) identified the armed status of subjects, as well as the precursor crime, as risk factors related to the outcome of lethal force. In both cases, there is a failure to focus on the progressing sequence of behaviours in officer-subject encounters over time, instead, treating them as static events. A further limitation mentioned by Shane et al. (2017) is that available data on the use of force incidents is often scarce and incomplete, restricting consistent results from statistical research. Early work by Binder and Scharf (1980) acknowledged the developmental processes that influence the use of force by separating incidents into four successive phases. The events in these phases, however, are limited to anecdotal and theoretical concepts, and not complex chains of specific behaviours. Without data that provides more information than statistics and theoretical concepts, the potential for in-depth understanding of the use of force is extremely limited. Data obtained from body-worn camera (BWC) footage may prove to be a valuable source of observational information for more detailed analysis.

Body-worn cameras were initially introduced to law enforcement to reduce use of force incidents, especially excessive force, by increasing the transparency of officer-subject encounters (Ariel, Farrar, & Sutherland, 2015). Officer BWCs provide a documented video record of subject encounters in real-time, and the post-encounter accessibility of footage is a valuable analytical tool for use of force incidents (Miller & Toliver, 2014). According to a review by Lum, Stoltz, Koper, and Scherer (2019), both law enforcement and the public have been generally supportive of the implementation of BWCs. However, this support predominately comes from isolated studies regarding jurisdictional decreases in use of force incidents and civilian complaints (Crow & Smykla, 2019). It is important to continue to grow the evidence-based literature on BWCs to better define their value and potential (Lum et al., 2019; Crow & Smykla, 2019). Of relevance to the current study, BWCs allow more information and evidence to be gathered about police-subject encounters, providing the observational data needed to map the complex patterns of such encounters as they unfold in real-time. To understand such complex, dynamic situations, a temporal method is required.

Behaviour sequence analysis (BSA) is a useful method for understanding the dynamic interactions between complex chains of behaviours. In BSA, chains of behaviours are parsed so that individual behaviours and behaviour transitions can be identified (Bakeman & Gottman, 1986; Clarke & Crossland, 1985). These behaviours are assigned specific codes that are recorded in the sequence in which they occur in an event (Keatley, 2018). The sequences of behaviour codes are then statistically analysed, determining the frequency that behaviour transitions occur, and calculating whether these transitions are significant and occurring above the expected level of chance. In the most common form of BSA, lag-one BSA, only single-step transitions between an antecedent (first) and sequitur (second) behaviour pairs are analysed (e.g., A → B, B → C); these behaviour pairs then form longer chains (Marono, Clarke, Navarro, & Keatley, 2018). Essentially, lag-one BSA aims to show that a sequitur behaviour follows an antecedent behaviour more likely than is expected by chance (Marono et al., 2018). Although higher-order sequence analysis is possible, wherein longer chains of behaviours can be mapped, it is not generally done. The main reason for this is that higher order sequence analysis leads to overfitting of data and other issues (Keatley, 2018). The comparison of the common pathways in lethal and non-lethal force incidents provides important information about the escalation of force in officer-subject encounters.

Behaviour sequence analysis has been successfully used in studies on false confessions (Keatley, Marono, & Clarke, 2018), non-verbal deception (Marono et al., 2018), and rape cases (Ellis, Clarke, & Keatley, 2017). Importantly, these studies apply BSA to the analysis of both verbal (Keatley et al., 2018) and non-verbal (Ellis et al., 2017; Marono et al., 2018) behaviours. The research performed by Ellis et al. (2017) demonstrated the successful application of BSA in identifying common pathways of behaviours that were likely to end in a sexual assault. In contrast, Marono et al. (2018) applied BSA to real-world footage of fabricated statements, in which the footage was seconds to minutes long. The adaptability of BSA in these studies (Ellis et al., 2017; Marono et al., 2018) suggests its potential for use in the analysis of BWC footage of officer-subject encounters.

Present Study

The aim of the present study was to explore the novel application of BSA to BWC footage of officer-subject encounters. BSA can identify common pathways of behaviours that result in the use of force, which can reveal critical points in each encounter where control of the situation is lost, and force is required. Identifying these points may be critical in preventing the escalation of force in officer-subject encounters, especially lethal force. Lethal and non-lethal escalations were analysed to show similarities and differences between these encounters. Importantly, this research counters data limitation as a single

application of force provides hundreds of behavioural data points. As this research using BSA is novel, no formal hypotheses were made; however, based on previous research into officer-subject encounters, a number of behaviours were expected to be observed in the data. For example, subject behaviours such as attacking and fleeing are frequently observed in the use of force incidents (Garner & Maxwell, 1999; Shane et al., 2017). Similarly, shouting, making threats, and the overall nature of communication between officers and subjects frequently influence the use of force (Garner & Maxwell, 1999). Furthermore, the continuums of force that law enforcement officers in the USA follow identified officer behaviours that were expected to be present when different levels of force were used (e.g., control hold, handcuffs; Garner et al., 1995).

Method

Sample

A sample of 40 videos was collected from freely accessible online media sites. These videos showed BWC footage from officer-subject encounters in the USA in which the outcome was lethal force ($n = 20$) or non-lethal force ($n = 20$). In all footage, there was a complex interaction between an officer(s) and subject(s) featuring an escalating sequence of behaviours. Inclusion criteria for each video were that all footage contained audio and were unedited from the time of arrival on scene to the application of force, as to be the most authentic representation of each officer-subject encounter. For the lethal force videos, the footage length ranged from 33 to 340 s ($M = 163.8$, $SD = 77.76$). For the non-lethal force videos, the footage length ranged from 16 to 407 s ($M = 195$, $SD = 116.3$). As the focus of BSA is to analyse behaviour sequences, the anonymity of all officers, subjects, and other individuals featured in all footage was maintained during analysis.

Coding Procedure

Prior to analysis, an initial behaviour list of officer and subject behaviours was generated by researching existing literature (Garner et al., 1995; Garner & Maxwell, 1999; Shane et al., 2017). If other behaviours were observed during analysis, they were added to the list to ensure that it was exhaustive, which is a prerequisite for sequence analysis (Bakeman & Quera, 2011). Each behaviour was assigned a letter code from A to Z, continuing to Aa-Za etc. Behaviour codes that were assigned to more than one officer/subject were coded with the relevant number value for more in-depth sequencing (e.g., A = officer 1 shouts, A2 = officer 2 shouts, A3 = officer 3 shouts). An important note for the behaviour codes is the separation between "officer shouts" (A[1]) and "officer shouts… 'stop' (R); 'drop weapon' (S); 'show hands' (T); 'get on the ground' (U)". These specific shouting behaviours are distinctly coded due to their direct explicit nature, whereas "shouts" is largely coded to show loud verbalisations were being made, but not clearly. The final behaviour list consisted of 118 behaviours that were used for sequencing.[2] Each video of BWC footage was viewed to sequence the behaviours observed during each officer-subject encounter, creating a data set of 40 different behaviour sequences (20 lethal force, 20 non-lethal force). The footage was slowed and rewound when required to produce the most accurate sequence of behaviours, particularly with seemingly simultaneously occurring behaviours. For increased reliability of the behaviour sequences obtained, the coding was conducted by two researchers with a third involved in resolving any discrepancies. Before analyses, the final behaviours and sequences were agreed upon. The list of behaviours and coded behaviour sequences are suitable for use in further research or on an expanded sample set.

Statistical Analysis

Once the BWC footage had been coded into behaviour sequences, the data was inputted into the statistical software, R, and run through a BSA program for analysis (R Core Team, 2013). The coded sequences for lethal and non-lethal force encounters were inputted separately as independent data sets for comparative interpretation. Firstly, the frequencies of individual behaviours and behaviour transitions were calculated; these frequencies were displayed in a transition frequency matrix.[3] Standardized residuals were calculated to identify significant transitions that were occurring above the expected level of chance. Any significant transitions were presented in a state transition diagram. Two state transition diagrams were developed using the lethal and non-lethal force data sets; however, due to the large number of behaviour codes, both diagrams contained a large volume of significant transitions. Therefore, the standardized residual threshold was increased so that only behaviour transitions with a standardized residual[4] (SR) above 3 were presented. This is a

[1] Note, the letter codes for behaviours are relatively arbitrary, "A", "U" etc. are codes used to make future coding easier and any letter could suffice, as long as each behaviour has a unique code.

[2] Available from corresponding author, on request

[3] Available from corresponding author, on request—they are omitted from publication owing to their size.

[4] The standardized residual is the metric of choice for BSA. It is the measure of difference between the observed and expected frequencies, calculated by the chi-square analysis. The SR gives an indication of which transitions are occurring above the level of chance. A cut-off of SR > 3 is used to make the diagrams clearer to read; full analyses of all transitions are available from the corresponding author on request.

common practice in BSA research (see Ellis et al., 2018, Keatley, 2018).[5] Notable behaviour transitions that fall below this threshold are still significant, although they are not presented to maintain a more visually understandable diagram.

Results

Frequencies

In total, 3792 behaviours were coded across 7175 s of BWC footage across lethal and non-lethal encounters. With 40 videos in the sample, this equates to 94.8 behaviours per officer-subject encounter, with a behaviour transition occurring every 1.89 s. The most frequent behaviours observed were "officer shouts", $n = 472$; "subject disobeys order", $n = 309$; "subject shouts", $n = 264$; and "officer addresses subject", $n = 211$. It is important to note that behaviour "officer addresses subject" is occurring in a conversational nature, separate from behaviours such as "officer shouts" and "officer shouts 'stop'" etc. Practically similar behaviours ("officer 1 shouts", "officer 2 shouts" etc.) were calculated together for more accurate frequencies of specific behaviours.[6]

Behaviour Sequence Analysis

The behaviour sequences from the officer-subject encounters were analysed using BSA to produce a transition frequency matrix for antecedent and sequitur transitions. The SRs calculated for each transition indicate the probability that each one is occurring above the level expected by chance alone (Keatley, Barsky & Clarke, 2016). Therefore, these SRs indicate interdependence between behaviours in the dataset (i.e. the antecedent behaviour makes the sequitur behaviour more likely to occur). Only transitions that are statistically significant, with frequency > 1 and SR > 3, are illustrated in a state transition diagram, showing how these transitions are connected in the dynamic of officer-subject encounters (Figs. 1 and 2). These cut-offs are standard approaches in BSA to reduce complexity of diagrams that would make them inaccessible to wider audiences (Ellis et al., 2017, Keatley, 2018). It is important to note that this particular analysis involved lag-one BSA, meaning that only pairs of behaviours were analysed. These transitions can be combined to create longer chains of significant behaviour sequences. By focusing on important behaviours of interest, such as the outcome of lethal or non-lethal force, common behavioural pathways can be mapped within the state transition diagram.

State Transition Diagrams

The state transition diagram for the lethal force data set can be seen in Fig. 1 ("lethal" encounters). Two common pathways were identified for the outcome behaviour "officer discharges firearm". The first pathway is "officer moves away from subject" to "officer draws lethal weapon" (SR = 6.07), and "officer points lethal weapon" to "officer discharges firearm" (SR = 10.85). This is the most common pathway as indicated by a thicker line connecting the behaviours in the state transition diagram. The second pathway is "subject charges at officer" to "officer discharges firearm" (SR = 6.07). Although this pathway is less common, it is still significant as it is displayed in the state transition diagram. This second pathway seems to start at "suspect charges at officer(s)" because the antecedents fall below the thresholds imposed. When the first officer points a weapon, this sometimes leads to another officer pointing their weapon, too (SR = 8.24). Officer 2 pointing a lethal weapon more often than would be expected by chance lead to Officer 2 discharging their firearm (SR = 13.06). A central cluster of transitions in the diagram focus around "suspect disobeys order". This is clearly a repeated behaviour in the dataset, and a focal point for escalation of conflict and perhaps confusion with so many antecedents and sequiturs.

The state transition diagram for the non-lethal force data set can be seen in Fig. 2 (non-lethal encounters). Two common pathways were identified for the outcome behaviour "officer discharges non-lethal weapon". The first pathway is "officer draws non-lethal weapon" to "officer points non-lethal weapon" (SR = 27.13). From pointing a non-lethal weapon, "officer discharges non-lethal weapon" followed more than would be expected by chance (SR = 7.72). Another behaviour seen after pointing a non-lethal weapon is also the officer shouting "drop weapon" to the suspect (SR = 10.89). While these pathways may appear obvious, they help to show the validity of the method—obvious pathways emerge clearly. To focus solely on this transition and dismiss the data as "obvious" would be to miss the point of the analyses—the complexity leading up to this point. Suspect disobeying orders is another central part of this sequence diagram, with multiple antecedents and sequiturs. There is, however, another central behaviour: "suspect resists", which also has many antecedents and sequiturs. From "suspect resists", "officer discharges non-lethal firearm" occurs more than would be expected by chance (SR = 8.57), and officer 2 discharges non-lethal firearm (SR = 3.23).

[5] Full diagrams and state transition matrices are available from the corresponding author, on request.

[6] It would be feasibly possible to analyse individual behaviours separately; but, this would make the analyses overly complex and fundamentally change the research question (into what is the effect of multiple officers—an important, but separate issue from the framework the current research is setting).

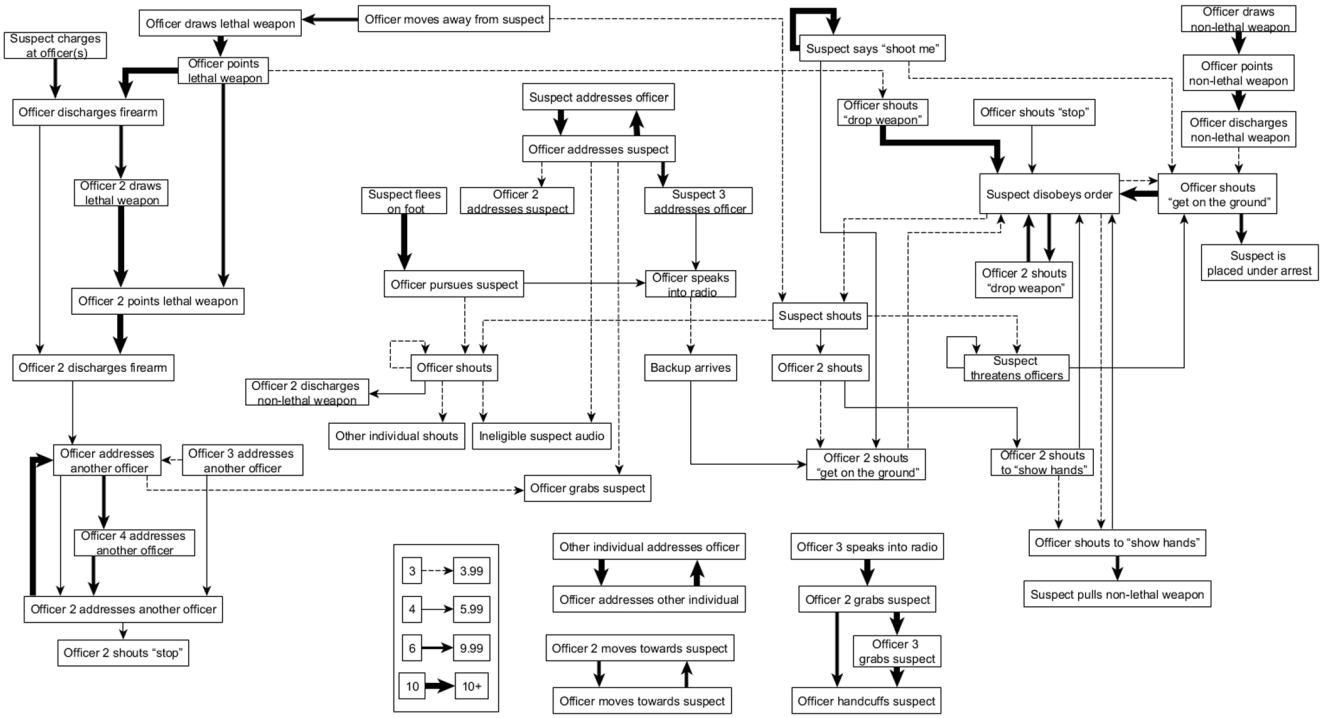

Fig. 1 State transition diagram of behaviours observed during officer-subject encounters where lethal force was used. *Note*. Key given at bottom. Lines indicate SR values

Discussion

The aim of this research was to apply behaviour sequence analysis to officer-subject encounters to better understand the escalation of force that occurs in lethal and non-lethal incidents. To the best of the authors' knowledge and literature review, a study like this has not been conducted before on this topic. The application of BSA to officer-subject encounters

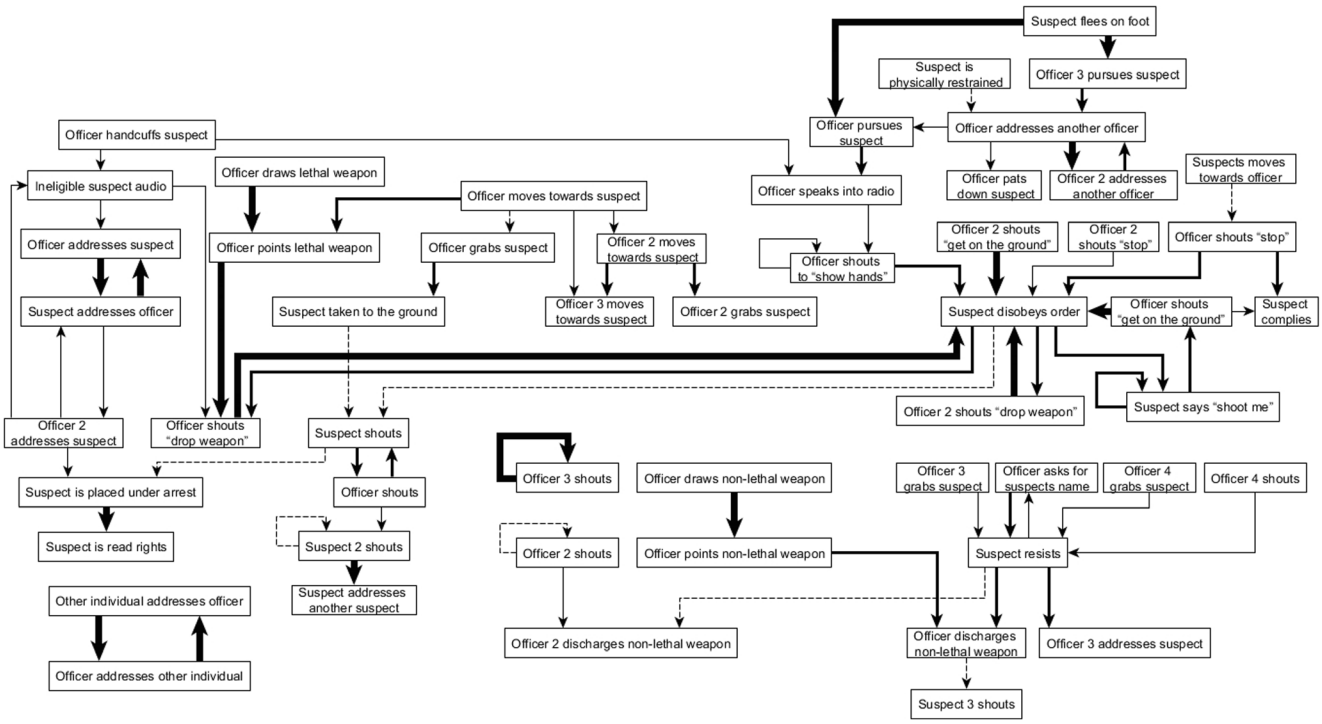

Fig. 2 State transition diagram of behaviours observed during officer-subject encounters where non-lethal force was used. *Note*: Key given at bottom. Lines indicate SR values

allowed us to analyse these events to a greater degree than previous research has been able to. The frequency of behaviours across the BWC footage emphasizes the importance of researchers analysing officer-subject encounters as dynamic and complex events. The findings are a clear demonstration of how complex and chaotic these encounters are, particularly in relation to the simplified force continuum that guides the legality and justification of force applications. Likewise, a behaviour transition occurring every 1.89 s supports Alpert's (2015) suggestion that officers are often required to make split-second decisions in high-stress and dynamic situations.

Findings show that the behaviour of a subject heavily influences the outcome of force used by an officer, which has been shown in previous research (Alpert, 2015; Shane et al., 2017). In the lethal force analysis, the common pathways indicate that more physically threatening behaviours are antecedents for the use of lethal force. Despite no antecedent transitions, the behaviour "officer moves away from subject" is, in a practical sense, suggestive of an officer perceiving a potential physical threat and moving themselves away from immediate danger. This behaviour is also highlighted as a key escalation point in lethal force encounters. In addition to being the initial behaviour in the first common pathway, it is also an antecedent for a sequence of verbally confrontational behaviours that result in the behaviour "subject is placed under arrest". Further analysis may be able to indicate what contextual factors may trigger this cascade in different encounters, and how this information may be used in de-escalation strategies. In the second lethal force common pathway, another physically threatening behaviour "subject charges at officer' is an antecedent for the transition to the outcome behaviour "officer discharges lethal weapon".

In comparison with lethal force incidents, the common pathways for the non-lethal force analysis show that verbally (or non-physically) threatening behaviours are antecedents for the use of non-lethal force. "Subject resists" is a sequitur for multiple verbally confrontational behaviours, as well as an antecedent for the outcome behaviour "officer discharges non-lethal weapon". In contrast to "subject charges at officer", "subject resists" and its association with other behaviours suggest a less physical threat towards officers, and thus, the use of non-lethal force over lethal tactics. Within the common pathways for non-lethal force, two behaviours are highlighted as key escalation points in these encounters. In addition to being the middle behaviour in their respective common pathways, "officer points non-lethal weapon" and "subject resists" are both antecedents for a sequence of verbally confrontational behaviours. Once again, these behaviours can be a point of interest for understanding the contextual factors in each encounter that trigger this alternate cascade of behaviours. Notably, the most common pathways for both lethal and non-lethal force outcomes are "officer moves away from subject", "officer draws lethal weapon", "officer points lethal weapon", "officer discharges firearm"; and, "officer draws non-lethal weapon", "officer points non-lethal weapon", "officer discharges non-lethal weapon" respectively. In both instances, it can be seen that the most common pathways for each force outcome involve an immediate reaction to a threat, with the withdrawal, pointing, and firing of each weapon in an uninterrupted sequence.

In addition to the behaviour of a subject influencing the outcome of force used by an officer, findings also demonstrate that the behaviours of an officer or multiple officers have a direct influence on how a subject behaves. This interaction between officer and subject emphasizes that these encounters need to be analysed as a complex sequence of events. The behaviour "subject shouts" in the non-lethal force analysis is a sequitur for multiple antecedent behaviours of officers ("officer 4 shouts", "officer 4 grabs subject", "officer 3 grabs subject", "officer asks subjects name"). It is alarming that these behaviours are antecedents for the outcome of force, as these verbal officer behaviours are some of the most frequently seen throughout the total data set. More specifically, most of these antecedent officer behaviours involve second, third, and fourth officers. It should be considered that a greater number of officers, especially when actively contributing to an encounter with a subject, may have different effects on the outcome. From these findings, limiting verbal conflict from officers and additional officer involvement during subject encounters, particularly those with an aggressive or threatening nature, should minimize the escalation to the use of force and should be the focus of law enforcement conflict training exercises. As a successful novel approach, this research would benefit from an increased data set allowing for common behaviour pathways to be mapped further from the outcome of force.

The different outcomes for each group (lethal vs non-lethal) may be explained by the perceived presence of an armed or unarmed subject, which cannot be identified as a significant isolated factor; however, it could provide some situational context for clarification. Previous research has linked traumatic experiences, such as those involving a weapon, with heightened senses in similar situations (Karlsson & Christianson, 2003). Therefore, it may not necessarily be the explicit presence of a weapon that leads to escalation, but that an officer perceived a greater threat than was present in reality, particularly if a subject is acting irrationally (Garner & Maxwell, 1999). Post-situation debriefs may be useful in gauging the officer's rationale for lethal escalation. While the inability to incorporate internal cognitive processes into the analysis is a limitation in the current research, BSA was able to identify interesting patterns of interactions between officers and subjects based on the behaviours and signs explicitly present in the videos.

One limitation came from the collection of data via BWC footage. These cameras are excellent for recording the events

of officer-subject encounters; however, in a practical sense, the footage was frequently difficult to interpret because the camera lens was obstructed by extended arms and because of the rigorous movement from the officers wearing them. This is a practical limitation in terms of post-hoc analyses. Additionally, the complexity of some encounters made sequencing every behaviour that occurred a difficult task, particularly when behaviours were occurring simultaneously or out of camera view. This is a well-documented limitation of BSA (see Keatley, 2018), and the accepted process is to slow the footage down enough so that the behaviour that begins first is coded first. More sophisticated sequence analysis methods (e.g., T-Pattern Analysis, (Magnusson, Burgoon, & Casarrubea, 2016; Magnusson, 2000) could be used to allow coding of multiple concurrent behaviours; however, these methods are seldom used and are much harder to follow. Included in these more complex analyses could be reference to contextual factors (e.g. lighting conditions, time of day, location information, and presence of bystanders) as well as an officer's mental processes that may affect their decision-making (e.g. perception of threat, prior history of subject, tactical considerations such as the presence of cover/concealment, and backup). All of these analyses would be beneficial to understanding police-involved lethal force encounters; however, the current manuscript is offered as a means of showing the benefits of the method. An aim is to show the method to more Police Departments in the hope they begin to see the benefits and share more data. Despite these limitations, BWC proved to be a valuable tool for analysing use of force incidents.

Conclusion

The behaviour sequence analysis was successfully applied to BWC footage of use of force incidents in officer-subject encounters. This successful application of BSA has filled in gaps of previous research that failed to treat officer-subject encounters as dynamic events. Through BSA, the common pathways of behaviours in both lethal and non-lethal incidents of force were able to be identified and compared, showing that physical threats from subjects led to the use of lethal force by officers, whereas verbal threats led to the use of non-lethal force. Furthermore, it was observed that subjects ultimately influence the force outcome of officer-subject encounters; however, the actions of officers heavily effect how subjects respond in each situation. Now that BSA has been successfully applied to the use of force incidents, the research can be expanded to include a greater sample size that will allow more specific contextual characteristics of encounters to be comparatively analysed and understood in the dynamic of officer-subject encounters.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Statement This article does not contain any studies with human participants performed by any of the authors.

Informed Consent N/A

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