MOBILE PHONE MOVEMENT BEHAVIOR IN STADIA FIRE EVACUATIONS

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ABSTRACT

In contemporary evacuation and pedestrian plan modelling there is a lack of data for spectator movement in stadia fires. Historical films from real stadium fire events are usually limited in camera angle and quality. They may also be too short in duration to fully describe the movement process, and too old to represent modern demographics and their behaviors. In recent years there has been a rise and dependency on information technologies such as mobile phones in stadiums which may influence the movement process in a fire evacuation of a stadium. As part of a comprehensive research program to study the influence of mobile phones (and other factors including alcohol consumption) on the evacuation and pedestrian movement in stadiums; with institutional ethics approved, herein these authors have conducted an analysis of a stadium fire during a sporting match that occurred in Canada in 2022 and introduce a stadium walkway data collection exercise conducted by them from 2023. In the stadium fire case study, a localized fire in a speaker occurred in the roof structure. The fire first prompted a localized evacuation of the stands possibly due to the fear of falling debris beneath. Later, a full evacuation and termination of game was called with the accumulation of smoke in the roofing structure. Through a controlled social media search from publicly available and accessible platforms, the authors obtained and analyzed 22 available videos of this evacuation of various durations. These videos were arranged and mapped chronologically with focus on percent egress with time in relation to events occurring in the stadium with additional study of mobile phone users in pre and eventual movement. The analysis included 106 identified mobile phone users. Their actions were categorized as: talking (phone to ear), texting (hand to phone) and filming (observing into screen). Combinations of these actions were also analyzed. These categories, where possible, were quantified in duration for pre (sitting) and post (moving). Filming actions of the fire were observed in over half of these spectators, with stationary (not moving) phone use being observed in the majority. Data collection of the walkway is introduced for the aspect of the study for movement speeds. As a progressive step towards modernizing human behaviour prediction models in emergency evacuations and normal circulation, the authors conduct a preliminary analysis and behavioral categorization exercise for modern behaviors such as mobile phone usage during sporting events for which currently data is brief or non-existent for use in modelling and analysis.

INTRODUCTION

Since 2016, the authors' research team have been working towards updating the parameters that affect modern human behaviour of stadium evacuations. Data collection exercises on people's behaviour and movement within stadiums have highlighted actions which have not been previously quantified. The most comprehensive summary of the author's previous work appears in a book by Gales et al., (2023) which summarizes human behaviour and their data collection studies of baseball, football, and tennis stadiums conducted between 2016 and 2019. Elsewhere, a comprehensive literary review is also included which details real fire evacuations such as Bradford (Young et al., 2021). Foundational studies such as SCICON (1972) and the work of Jake Pauls exist among others for reference on the topic. The reader is encouraged to consult these materials for a more thorough background on the topic of movement in stadia. While accessibility considerations in evacuations

have been the focus of the authors' in previous work, and general evacuation in the work of others, only recently has research on stadium evacuations included the topics of alcohol use and mobile phone usage (Gales et al., 2024). There is clear demand for this mobility data of individuals for improving evacuation data for modelling. For example, more recent studies have shown the increase in mobile phone usage in the general population in recent years (Chemnad et al., 2022) and further, Young et al., (2021) observed mobile phone users in a stadium fire event where behavioral actions included at least 16% of people filming in the stand vicinity of the fire (stand capacity being 120). These users were observed to physically obstruct egress. Given the potential effects of mobile phone users in stadia on movement, it is prudent to discuss available literature on the topic of mobile phone use and how it may influence evacuation prior to presenting a detailed study on the topic of available videos of a real fire in 2022 and a novel data collection exercise conducted in 2023 which focuses on mobile phone users and movement.

BACKGROUND RESEARCH ON THE INFLUENCE OF MOBILE PHONE USE AND MOVEMENT

A simplified key search in general databases was performed to consider associate literature. Using the key words of 'mobile phone' in association with 'movement', 'gait', and 'physical behaviour', as well as combination phrases such as "cell/mobile phone usage in stadium evacuation", "cell/mobile phone pedestrian behaviour", "cell/mobile phone crowd movement" and "cell/mobile phone stadium crowd movement". Sixteen potentially relevant studies of application were analysed. Ten of which were used herein of more specific context. Studies involving stadiums specifically were not found in the authors' search. Various studies have been conducted measuring the impact of individuals' physical and movement behaviours when performing different tasks on mobile phones (see Bovonsunthonchai et al., 2020 for example). The individuals that participated in the below studies have consisted of older, younger, university students, male, and female. The aim of these studies examines and verifies the effects on pedestrian performance while being subjected to dual tasks of walking and using mobile phones. Prupetkaew et al., (2019) conducted a study in a laboratory setting that mimicked the behaviour of walking. A virtual environment was created with an integrated treadmill to resemble participants walking. This helped achieve a real-world simulation of street crossing effects. Participants were requested to perform dual tasks consisting of crossing or standing on simulated streets created from treadmill whilst listening to music, conversing on phone (playing a game, reading, writing an email, texting one person or a group), or being undistracted. Crowley et al (2017) had participants attach accelerometers to either side of their shoes to help measure movement velocity, length, cadence and double support time. It was observed through Rina Márcia Magnani et al (2017) that young healthy adults subjected to walking and texting adapt their movement pattern due to the increase in attentional demand of using a mobile phone. This dual task performed by young individuals showed a significant decrease in cadence, stride length, movement velocity, larger movement variability, higher mental workload, walking speed, and lower comprehension compared to reading. It was also observed that there was an increase in coefficients of variation of stride, cadence, length, and double support time at various walking speeds. Plummer et al. (2015) observed young adults tend to weave more when texting and walking as they do not modify walking and texting behaviours in high-distraction environments, creating an unsafe environment where young adults are at a greater risk of trips, falls, and slips. Older adults, compared to younger adults, are more vulnerable to dual-task impairments when the crossing task was challenging. Older adults' street crossing performance decreased when performing dual tasks compared to single tasks (Ehlers et al., 2017). They were less likely to complete crossing when compared to being undistracted or listening to music. The effects of walking with distraction were minor when performed at a self-selected fast walking speed compared to normal walking. Silva et al. (2019) determined that older adults show large deterioration in obstacle detection when message deciphering resulting in higher risk of collision. Text messaging prolongs older adults' recognition of approaching pedestrians, compromising safe ambulation within their community. Bruyneel et al.,

(2020) also conducted a study on individuals (age unspecified) showing the use of mobile phones, not considering music or undistracted walking, can slow down movement. Texting on a mobile phone creates a greater interference on walking than talking on a mobile phone. Playing a game on the mobile phone was shown to be the most cognitively demanding task, leading to the greatest performance degradation (see Labonte-LeMoyne et al., 2022). This is due to the increased cognitive distraction reducing an individual's situational awareness, leading to an increase in unsafe behaviour. Performing these dual tasks can interfere with working memory, executive function, movement, and result in walking errors. Texting ultimately results in a slower movement. The level of difficulty of movement tasks was not shown to be proportional to the degree that said movement slows (see Strubhar et al., 2017). A more challenging movement task however resulted in an increase in both texting errors, path deviations, and decreased texting speed. These findings conclude that, generally, increased dual tasks result in decreased efficiency in walking and texting performance.

Literature indicates that individuals being subjected to dual tasks using mobile phones will see physical behaviour effects. It has been found that movement, speed, and cadence will decrease when individuals are texting, or playing games on their mobile phone. But if the individual is listening to music on their mobile phone device, their physical behaviour appears to remain unaffected, at least in the studies shown. Younger adults tend to weave more when texting on their mobile phone, while older adults have a higher risk of collision, which may associate to familiarity with devices.

DATA COLLECTION METHODOLOGY OF STADIUM FIRE

York University ethics office was contacted regarding policies and procedures for the secondary analysis of publicly available video files of a specific fire event. An HPRC (Human Participant Research Protocol) form was submitted and reviewed by the university ethics panel. A letter of authorization, in accordance with university policy on secondary analysis, was then given to the authors which permitted the ethical analysis of these video files for this study.

The structural aspects of the stadium fire and its circumstances / timeline have been reported elsewhere (see Chin et al., 2024). This paper also details the degree of fire protection stadiums are typically specified in codes. In brevity for this stadium fire, a speaker fire occurred which prompted a localized evacuation while play of the match continued. This was a ‘slow’ egress relative to later egress. The fire continued creating a large smoke presence which then prompted a full evacuation and stoppage of the sporting event in progress (a professional league) which was relatively faster. Tickets were refunded for those attending amounting to direct revenue losses of 2 million dollars (CAD) from tickets plus indirect associated concessions, TV/Media, sponsor costs etc.

The analysis of mobile phone users (as well as those who were visibly confirmed to be drinking but is a part of a companion study which will be presented in a future publication) was performed through an in-depth search through multiple social media platforms. The platforms included in this search considered: TikTok, Twitter (currently being referred to as X at the time of writing), Instagram, Reddit, YouTube, and local news outlets (stations redacted to preserve anonymity). These media platforms helped determine the number of spectators egressing with time and characteristics of those using their mobile phones during the fire event in the stadium. No members on the research team were present during this fire event. Key features of the unique aspects pertaining to the event that took place were used to search on various social media platforms. These words referenced the location, the primary team involved, unexpected nature of the event, and the object. Specific keywords used in hashtags and search bars across various social media platforms were “home team name”, “home team stadium name”, ‘speaker’, and ‘fire’. The keywords were then turned into key phrases searched throughout these platforms such as “[home team stadium name] arena fire”, “[home team name] fire”, “[Home team name and stadium name] fire”, “[home team stadium name] speaker fire”, for a more in-depth search of the event. The choice of phrases is somewhat arbitrary

though focused on the key theme observed. It is acknowledged that real fire case studies are rare. These public videos found were then assessed to the relevance of the study. For a video to be considered in the study it needed to follow criteria such as showing the audience in the stadium, and/or showing fire-related content. Videos displaying selfies, or imagery of outside the arena, and only smoke were not used in this study and disregarded. Twenty-two videos were collated. Videos following the criteria listed above were then downloaded and analyzed as MP4 files and assessed. Videos were paused and zoomed using software to determine the number of spectators and their behavior using mobile for pre (sitting) and post (moving) actions. An excel spreadsheet was created consisting of several categories such as: time relative to the evacuation, general location in the stadium, the image of said person, the type of usage (classified as either filming, phone call, texting, looking, resting in hand, checking phone, and walking with it in hand), and finally logged if it was a pre or post movement action. A summary of available videos is presented in Table 1. The cumulative evacuation with full certainty points is presented in Figure 1. This is indicative of the total evacuation time stamp, and inclusive of the local evacuation time in the stands. The basis for Figure 1 follows the assumption that the stadium was full n=19800 (confirmed by evening attendance as a sellout) and that the number of empty seats at a specific time correlates to the number of those evacuated. Five researchers of the team completed this task to ensure reproducible results (where not listed as authors these people are listed in acknowledgements).

Table 1: Description of videos obtained of stadium fire

Video #	Short description	Source
1	Fire investigation	TV
2	Fire announcement evacuation	TV
3	Concourse	TV
4	Speaker on fire	TV
5	Close up of speaker on fire	Twitter
6	Bottom view of speaker	Twitter
7	Fire dept clearing out section below speaker	Twitter
8	Video of whole event (sequence of 4 compiled videos)	Twitter
9	Fans evacuated after fire at stadium	News
10	Floor seat view of evacuation	Instagram
11	Comparison of during the game (evacuation shows at the end of the video)	Instagram
12	Last slide shows evac	Instagram
13	Underneath shot of the fire	TikTok
14	Far side profile of the fire	TikTok
15	Near Side profile of fire	TikTok
16	Video of evacuation of people	TikTok
17	Sound of fire alarm	TikTok
18	Announcement of fire and full evacuation	TikTok
19	Reporting and evacuation	YouTube
20	Teams leaving while crowd stays	Twitter
21	Speaker on fire while play continues	Twitter
22	Video of the speaker on fire	Reddit

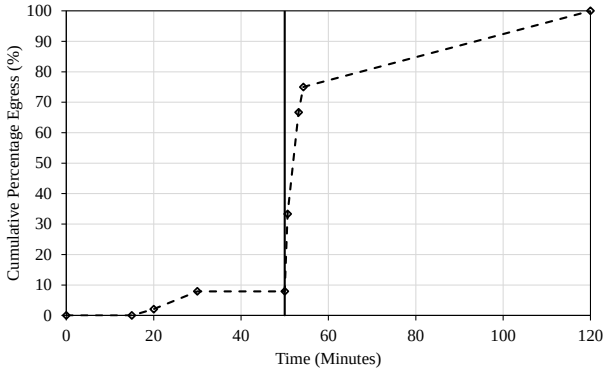

Figure 1: Cumulative percentage egress of stadium fire (2022)

DATA COLLECTION METHODOLOGY OF STADIUM WALKWAY STUDY

While the data collected at the stadium fire has interesting aspects associated to users, the videos are not controlled as to filming locations and have limited use to derive specific quantifiable movement characteristics that may be desired by researchers and practitioners. It is not inherently possible to derive more specific speed characteristics or general percentage trends of these users, and this is both an interest and needed. Therefore, following the fire case study, these authors have been conducting a data collection exercise at the York University professional sports stadium during a professional tournament (see Gales 2023 for stadium description) under ethics protocol STU 2023-078. The first day and quarterfinals were observed in detail of this tournament. The effort is both to derive specific movement patterns of users and more specific percentage of active users of phones for the stadium's total population. This exercise can be used to place the analysis above in further detail. For the controlled data collection, the authors aimed to analyze the population by manually counting the number of people moving within a designated circular area (the village) and within the walkway over two different days: during a general match and then during the quarterfinals of a tournament with a total population of over 10,000. This manual counting method provided a direct and reliable way to gather data on the crowd movement within the stadium – particularly those who utilized mobile phones. These users were tagged with time to allow extraction of movement profiles in future analysis. This methodology will also be used to derive population densities and validate a LiDAR technology which automates the counting process but is a separate objective from this study. The introduction of this analysis and that of the data collection exercise performed can be referred to from Young and Gales (2024). The manual count was concluded in summer of 2024 and will be validated among other team members for completeness in the future months before final publication (hence preliminary). The count was conducted each minute. Perimeter measurements were taken on-site during land surveying to find the area and therefore density for the LiDAR validation.

ANALYSIS AND DISCUSSION OF STADIUM FIRE

While the results are preliminary and under analysis at the time of presentation and writing, several conclusions may be drawn in the addition of the identification of more specific research studies in more controlled data collection exercises. The observed mobile phone users in the videos represent a distinctly low proportion of the total population, excluding the individuals who were actively filming the videos obtained, 106 distinct individuals were observed of which 80 were observed during the full evacuation process (when the game was stopped). Thirty-eight can be confirmed to be visibly moving while using the phone (Figure 2). In one observable instance, a mobile phone user trips over garbage left in the stands as they are looking at their screen. Videos and film are limited to the individuals observed travel journey, hence the authors in this case do not and cannot derive

movement speeds as their full path is not recorded nor can a percentage of users actually be established as some are not seen during the full evacuation to whether they use or do not use a mobile phone in their journey. Though this value may be small in proportion though in need of further study. Most users of phones were actively filming or looking for information on their phones. They were not in the process of movement when using their phones in majority. Many of these spectators are young to middle age, and no individuals with accessibility aids were observed using mobility aids (at least in the film seen). It must be noted that the data herein correlates to the availability of film collected. I.e., most people information sought/filmed once the evacuation began. Table 2 illustrates the frequencies of observed actions.

Figure 2: Example of a mobile phone user during evacuation

Table 2: Observed actions with definition

Term	Definition	# of observed
Talking	Phone to ear/side of head, assumed to be on a phone call with someone	14
Texting	Phone in hand, head looking down at phone, not necessarily texting but phone usage is occurring	44
Filming	Phone in handheld close to head height away from body, facing towards event that is occurring	48

ANALYSIS AND DISCUSSION OF STADIUM WALKWAY STUDY

From the collected and analyzed data as applicable to this study, the event's quarterfinals were used for analysis. It was observed that there was a total of 1,003 mobile phone users in the walkway (just over 10% of the total observed population) during the quarterfinal day of the tournament, of this small proportion, 68% of whom were standing in one place as they used their phones. This statistic suggests that most of the people preferred to stand still while using their phones (as replicated by the stadium fire observation) while there was still a statistically large number of people moving while using their phone (future work will derive movement speeds and patterns). However, it is important to note that the count was done per minute for consistency, so some individuals standing in one place were likely counted more than once. Additionally, the walkway was a common area where people were waiting in line for the restroom, which could have contributed to stationary phone users.

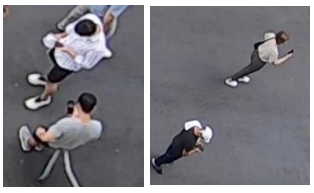

Figure 3: Example of mobile phone users in the stadium walkway

CONCULSIONS

This study's findings are crucial for understanding how phone usage may impact crowd movement and congestion within the stadium. This data can inform strategies for improving crowd management and safety protocols in similar environments. While preliminary, these general conclusions are that the populations exist to cause congestion during evacuation who use mobile phones, that the proportion of these users is potentially small, and that that proportion is generally stationary when using their mobile phones. The population is, however, large enough to cause effects on egress and should have more detailed analysis as this study continues.

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