The Impact of Social Influence and Threat Uncertainty on Behavior in a School Shooting Simulation

Kevin Kapadia[a*], Nutchanon Yongsatianchot[b], Katie Byrd[a], Stacy Marsella[c], Richard John[a]
[a]University of Southern California, Los Angeles, U.S.A.
[b]Faculty of Engineering, Thammasat School of Engineering, Thammasat University, Pathum Thani, Thailand
[c]Northeastern University, Boston, U.S.A.

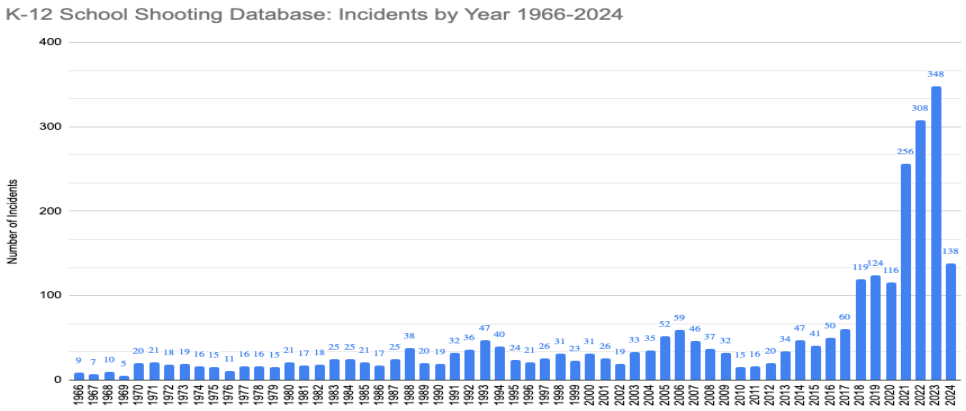
Abstract: As the frequency of school shooting incidents grows in the United States, understanding student behavior in response to shootings is crucial for policy development. A total of 545 participants from Prolific.com participated in an immersive virtual experience on a computer screen of a school shooting simulation using a 3x3 factorial design varying social influence (all run, all hide, or mixed) from non-player characters (NPCs) and threat uncertainty (high, medium, low) from proximity to where shooting begins. Results showed that participants were more likely to hide as more NPCs hid in high and medium threat uncertainty conditions. However, when threat uncertainty was low, participants were most likely to hide in the mixed social influence condition. Similarly, participants were more likely to evacuate as more NPCs ran away in the high and medium threat uncertainty conditions. However, this effect was not significant when the threat uncertainty was low. Participants reported a significant increase in negative affect after completing the simulation; approximately 40% reported that NPCs influenced their behavior, and 25% reported that they had received active shooter training before. Our findings suggest that individuals in a school shooting are likely to follow the social influence of others, whether they realize it or not. Furthermore, this effect is strongest when the uncertainty of the threat is high. These insights can help policymakers construct more effective guidelines for how individuals should respond to school shooting scenarios and reduce casualties.

Keywords: social influence, threat uncertainty, simulation, school shootings.

1. INTRODUCTION

The prevalence of school shootings in the United States has risen dramatically in recent years, highlighting the need for effective mitigation measures. The K-12 School Shooting Database (2024) recorded 348 incidents in 2023 alone, marking the highest number in the database from 1966 to 2024. Before 2020, no year had more than 125 incidents; yet, since 2021, the annual average has increased to 257. Figure 1 shows the full number of school shooting incidents by year. Additionally, from 2021-2023, there was an average of 237 victims (fatal and wounded) on K-12 property per year. This alarming trend highlights the severity of the threat posed by school shootings and the necessity for strategies to mitigate their impact. These events' increasing frequency and lethality call for a better understanding of the factors contributing to their occurrence and the development of robust response protocols.

Figure 1. Number of School Shooting Incidents by Year



In response to the growing threat, the Federal Bureau of Investigation (FBI) has endorsed the "Run, Hide, Fight" protocol as a guideline for individuals caught in an active shooter situation (FBI, 2022). This model advocates running to safety when possible, hiding if escape is not feasible, and fighting as a last resort. While this protocol provides a clear action plan, its effectiveness in real-life scenarios is often questioned. Research indicates that individuals' behavior under extreme stress can deviate significantly from trained responses, influenced by panic and the immediate environment (Worthington et al., 2021; Zhu et al., 2020). Studies have shown that crowd behavior during such events is complex and often dictated by social influence and threat perception, making it challenging to predict outcomes based solely on the "Run, Hide, Fight" guidelines (Drury et al., 2009).

Simulation studies have been instrumental in understanding behavior during school shootings. Bott (2021) examined reinforcement learning for active shooter mitigation, demonstrating how simulations can inform response strategies. Zhu et al. (2020) conducted focus group interviews to build preparedness for active shooter incidents, emphasizing the importance of realistic training environments. Awada et al. (2021) integrated emotional and physiological assessments in VR-based experiments, highlighting the impact of stress on decision-making during such incidents. Zhu et al. (2019) investigated the information requirements for virtual environments to study human-building interactions during active shooter incidents.

Meanwhile, Zhu et al. (2022) analyzed the impact of security countermeasures on human behavior during these events. Bahmani et al. (2023) reviewed students' evacuation behavior during school emergencies, providing insights into effective evacuation strategies. Zhu et al. (2023) used machine learning and discrete choice models for behavioral, data-driven, agent-based evacuation simulations, contributing to building safety design. Arteaga et al. (2023) studied the effect of trained evacuation leaders on victims' safety during active shooter incidents, demonstrating the value of leadership in emergencies. Liu and Becerik-Gerber (2022) examined human and building digital twins for VR-based building emergency training, showcasing advanced simulation technologies in preparing for active shooter scenarios.

Our study builds on this research by using an immersive virtual simulation to observe how participants respond to varying social influence and threat uncertainty levels. This method collects empirical data in a realistic setting, providing insights into decision-making processes during school shootings. We do not restrict the sample to current students as previous studies (Zhu et al., 2019) have validated the behavior of a general sample in estimating behavior in response to an active shooter of a specific segment of the population (office workers). Furthermore, schools have adults working as staff or visiting who would also be present during an active shooter scenario. The findings from our simulation can refine existing models and enhance training programs for school safety. In this study, we aim to answer the following research questions. 1. How does proximal social influence impact whether participants run away or hide? 2. How does threat uncertainty impact whether participants run away or hide? 3. How does the interaction between social influence and threat uncertainty impact whether participants run away or hide? 4. How do participants' positive and negative affect change in response to the simulation?

2. METHODS

2.1 Study Design and Participant Information

We recruited 545 participants from Prolific.com, an established source of high-quality online participants for behavioral research (Douglas et al., 2023). We randomly assigned participants to one of nine conditions capturing all combinations of the behavior of 37 NPCs (all running from the shooter, all hiding, or a 50-50 mix of running and hiding) and uncertainty of the threat (high, medium, and low). Figure 2 displays a map of the school used in the simulation. Shooter proximity to participants serves as a proxy variable for uncertainty surrounding the threat, with closer proximity corresponding to lower threat uncertainty. The shooter starting at the east exit (high uncertainty) results in the greatest starting distance from participants, followed by the front entrance (medium uncertainty), while the cafeteria (low uncertainty) is the closest to where participants start. The levels of potential social influence others' actions have on participant behavior are named after the behavior of the NPCs in each condition. Table 1 displays the sample size for each condition in the study. Sample sizes vary from 53 to 69 due to attrition from participants not completing training within the required time (15 minutes).

Figure 2. Map of School Used in Simulation

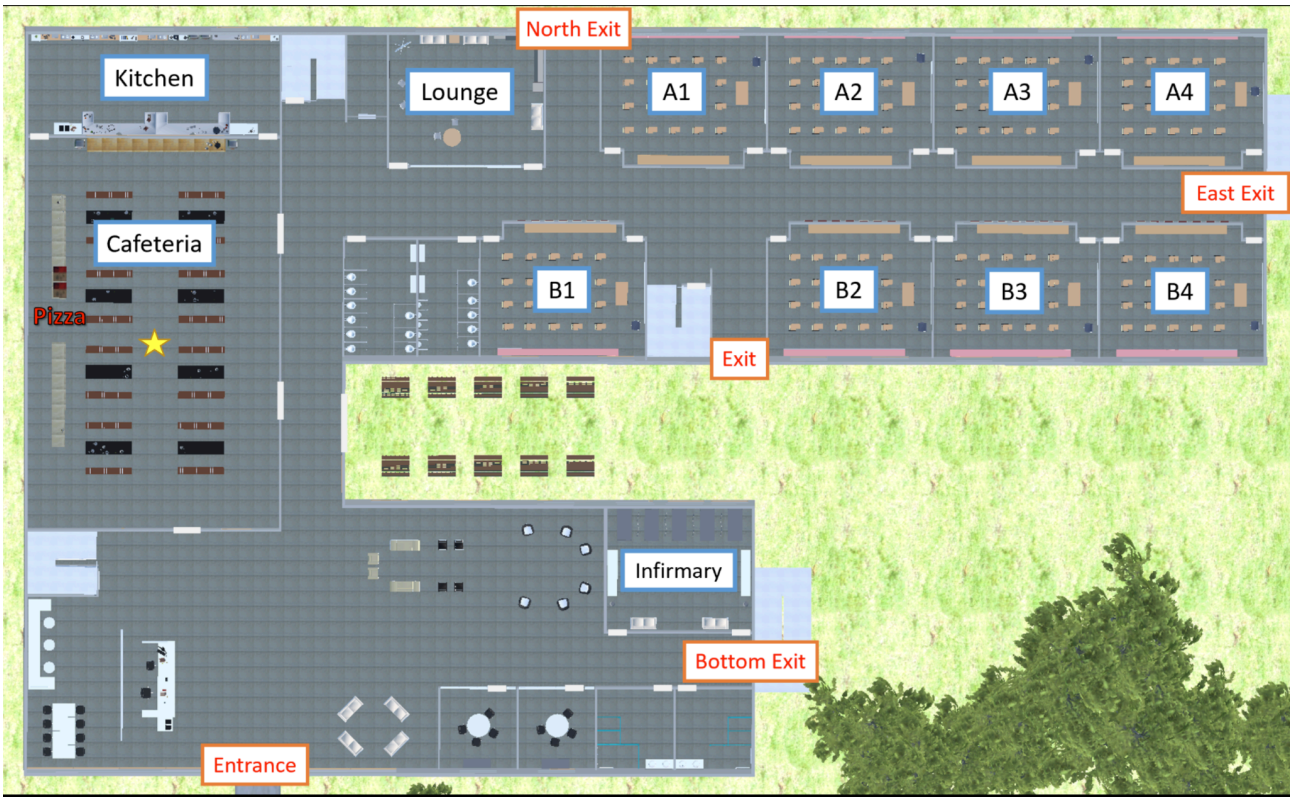


Table 1. Sample Size for Combination of Social Influence and Threat Uncertainty Conditions

	High Threat Uncertainty	Medium Threat Uncertainty	Low Threat Uncertainty
Run Social Influence	61	56	69
Mixed Social Influence	66	54	53
Hide Social Influence	59	62	65

All participants began by consenting to participate in the study and then completed a brief version of the Positive and Negative Affect Schedule (PANAS). The PANAS is a psychological tool used to measure an individual's positive and negative affect (Watson et al., 1988). Our brief version included five positive and five negative affect words for which participants rated how they felt from 1 (very slightly or not at all) to 5 (extremely). Before participants played the simulation, they were asked about their affect during the past week, and after the simulation, participants were asked about their affect in the moment.

Participants then completed two training sessions and the simulation described in the next paragraph. Following the simulation, participants completed the same PANAS items and answered questions regarding their experience with the simulation and active shooter scenarios in general. Participants ended the study by answering demographic questions related to age and gender. Participants' mean (SD) age was 37.14 (10.99), and 56.68% were male. Participants were compensated $3.00 upon completing the study, with a median completion time of 15 minutes and 40 seconds, approximately $11.49 per hour. Only 4.96% of participants indicated they had experienced an active shooter situation, while 25.57% reported receiving active shooter training. Of the participants who reported receiving active shooter training, only 40.30% indicated they followed the training during the simulation.

2.2 Simulation Procedure

Data for this study was collected using the Unity game engine to construct a 3D model of a school to create an immersive environment. Prior to the simulation, all participants engaged in two training sessions. In the first session, participants practiced movement using their mouse and keyboard. After passing this training, participants navigated to 7 locations within the school to help familiarize them with the layout. Only if participants completed both training sessions in under 15 minutes did they participate in the actual school shooting simulation. All participants began the simulation in the cafeteria (denoted by the star in Figure 2) and heard gunshots after 3 seconds. At this time, the NPCs begin running or hiding, depending on the condition. The simulation lasted a maximum of 70 seconds, ample time for those choosing to run to exit the school. Participants could go wherever they wanted but could not pass through boundaries or other NPCs. Participants were also not targeted by the shooter to avoid data censoring from early termination. Figure 3 displays selected photos from the simulation. From left to right in the top row, the photos represent how participants practiced movement and the main hallway during the tutorial to familiarize participants with the school. In the middle row, the photos represent the cafeteria where participants began the simulation and an example of NPCs hiding from the shooter. In the bottom row, the photos represent an example of NPCs running from the shooter and the shooter.

Figure 3. Selected Screenshots from Unity Simulation

3. RESULTS

3.1 Observed Participant Behavior During Simulation

Using participant coordinate data, we defined the following behaviors in the simulation: (1) hiding was defined as the participant crouching and not moving, (2) sneaking as crouching and moving, (3) standing still as not crouching and not moving, and (4) running away as not crouching and moving. Figure 4 summarizes the most common behavior participants engaged in conditional on social influence and threat uncertainty. In the high and medium threat uncertainty conditions, participants were less likely to run away and more likely to hide as the social influence shifted from more NPCs running to hiding. However, when the threat uncertainty was low, participants ran away the most in the run social influence condition and the least in the mixed.

Figure 4. Percent of Participants' Most Common Behavior Exhibited by Social Influence Condition and Threat Uncertainty. The error bars represent 95% confidence intervals.

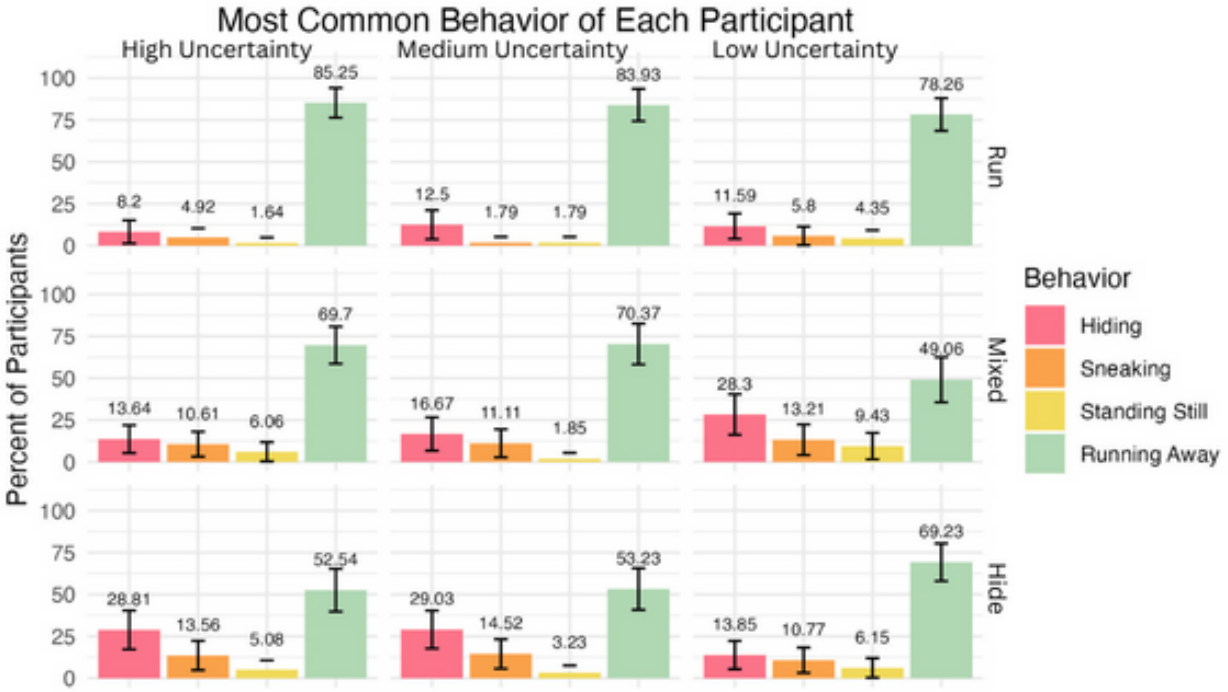


Table 2 summarizes the results of a binary logistic regression (BLR) where social influence, threat uncertainty, age, and sex predict the likelihood that participants spend most of the simulation hiding. The Tjur's R-squared value was 11.0%. Results show participants were 1.64 times more likely to hide in the hide social influence condition than to run. Additionally, females were 4.35 times more likely to hide compared to males. Finally, participants were 1.95 times more likely to hide when the social influence was mixed and the threat uncertainty was low. No other interaction effects were significant.

Table 2. Summary of a BLR Predicting if Participants Spent Majority of Time Hiding

Predictor	**Odds Ratio**	**95% Confidence Interval**	**p-value**
Intercept	0.23	0.10 – 0.57	**0.001**
Social Influence Condition [Run and Hide vs Mixed] (1)	1.14	0.79 – 1.62	0.483
Social Influence Condition [Hide vs Run] (2)	0.61	0.44 – 0.84	**0.002**

Threat Uncertainty [Medium and High vs Low] (1)	0.97	0.67 – 1.39	0.871
Threat Uncertainty [High vs Medium] (2)	1.16	0.85 – 1.59	0.362
Age	1.01	0.99 – 1.04	0.274
Gender [Females vs Males]	0.23	0.14 – 0.39	**<0.001**
Social Influence Condition (1) x Threat Uncertainty (1)	1.95	1.20 – 3.22	**0.008**
Social Influence Condition (1) x Threat Uncertainty (2)	1.23	0.77 – 1.95	0.382
Social Influence Condition (2) x Threat Uncertainty (1)	1.08	0.68 – 1.70	0.751
Social Influence Condition (2) x Threat Uncertainty (2)	1.16	0.80 – 1.72	0.437

3.2 Percent of Participants Who Evacuated From the School

Figure 5 summarizes the percentage of participants who decided to evacuate by social influence and threat uncertainty. In all threat uncertainty conditions, as more NPCs ran, participants were more likely to run; however, this effect is the weakest in the low threat uncertainty condition. Approximately twice as many participants evacuated in the run-high uncertainty condition than in the hide-medium uncertainty condition.

Figure 5. Percent of Participants Who Evacuated by Social Influence Condition and Threat Uncertainty. The error bars represent 95% confidence intervals.

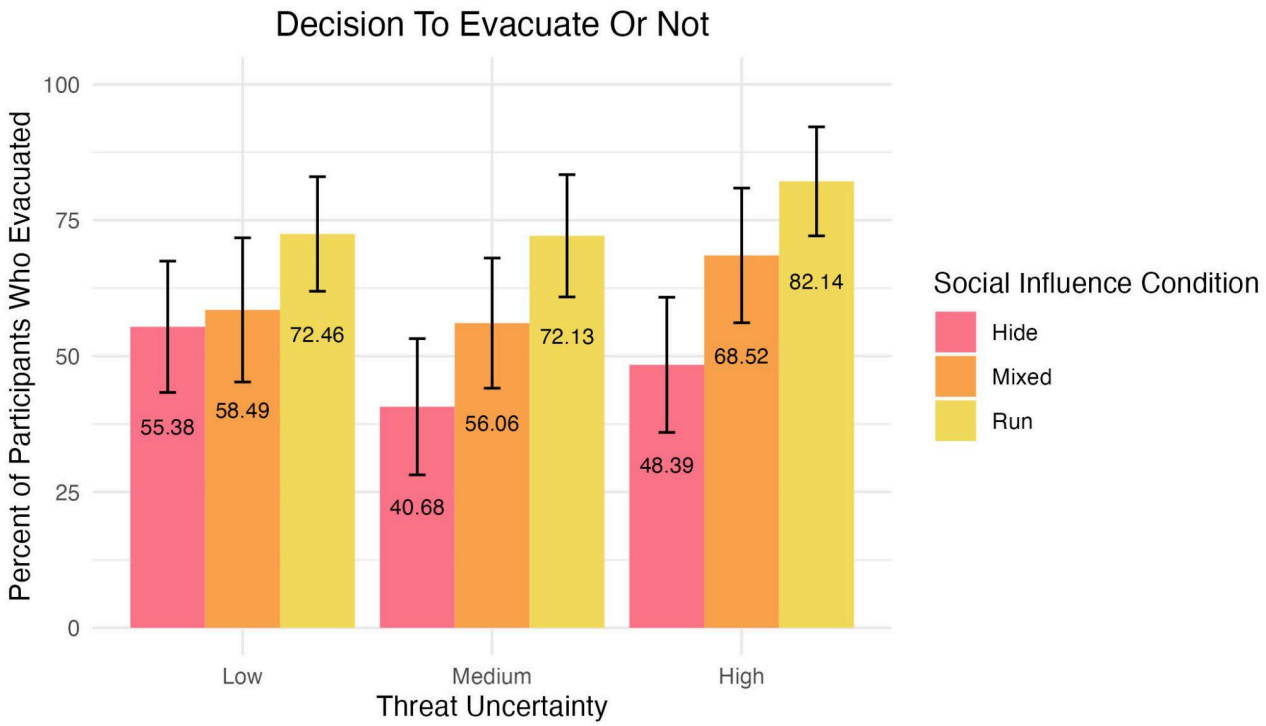


Table 3 summarizes the results of a BLR where social influence, threat uncertainty, age, and sex predict the likelihood that participants will evacuate from the school or not. The Tjur's R-squared value was 11.1%. Results show that participants were 1.92 times more likely to evacuate in the run social influence condition than in the hide. Additionally, participants were 1.29 times more likely to evacuate in the medium threat uncertainty threat condition than in the high uncertainty condition. Finally, males were 2.50 times more likely to evacuate compared to females. No interaction effects were significant.

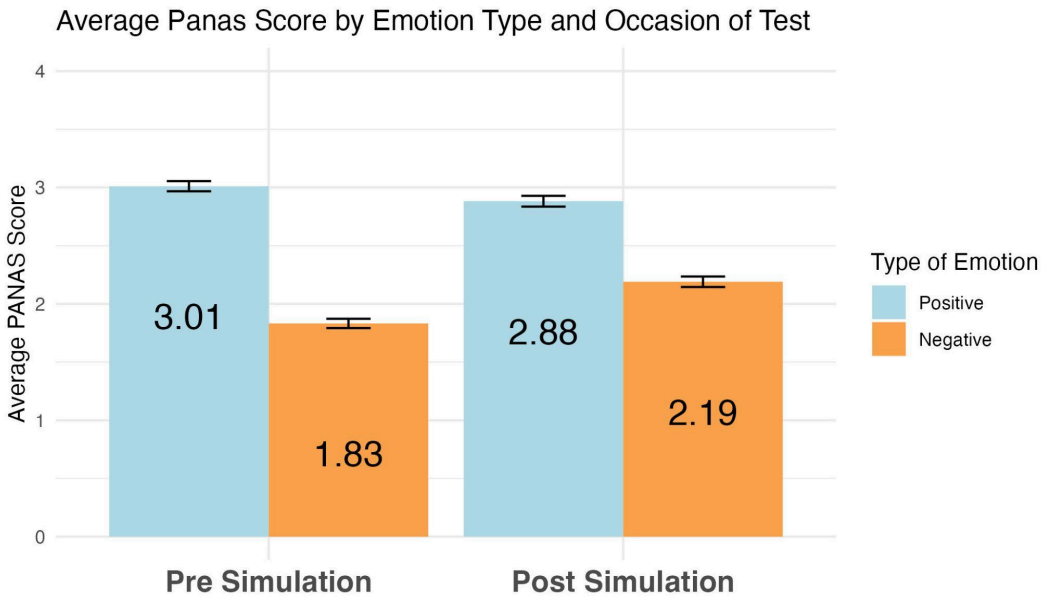
Table 3. Summary of Logistic Regression Predicting Evacuation Outcome

Predictor	**Odds Ratio**	**95% Confidence Interval**	**p-value**
Intercept	1.72	0.86 - 3.44	0.128
Social Influence Condition [Run and Hide vs Mixed] (1)	0.93	0.71 - 1.22	0.617
Social Influence Condition [Hide vs Run] (2)	1.92	1.51 – 2.44	**<0.001**
Threat Uncertainty [Medium and High vs Low] (1)	1.03	0.79 – 1.35	0.816
Threat Uncertainty [High vs Medium] (2)	1.29	1.02 – 1.64	**0.038**
Age	0.99	0.97 – 1.00	0.107
Gender [Females vs Males]	2.50	1.71 – 3.70	**<0.001**
Social Influence Condition (1) x Threat Uncertainty (1)	0.84	0.57 – 1.24	0.380
Social Influence Condition (1) x Threat Uncertainty (2)	0.82	0.59 – 1.15	0.250
Social Influence Condition (2) x Threat Uncertainty (1)	0.99	0.71 – 1.38	0.941
Social Influence Condition (2) x Threat Uncertainty (2)	1.02	0.76 – 1.38	0.904

3.3 Affective Responses to the Simulation

Figure 6 displays positive and negative affect before and after the simulation. For the positive items, results indicated a significant decrease in the score of positive affect from before the simulation (M = 3.01, SD = 1.14) compared to after (M = 2.88, SD = 1.21) the simulation, $t(2619) = -7.60$, $p = <.001$, $d = 0.15$). For the negative items, results indicated a significant increase in the score of negative affect from before the simulation (M = 1.83, SD = 1.04) compared to after (M = 2.19, SD = 1.18) the simulation $t(2619) = 18.84$, $p = <.001$, $d = 0.37$).

Figure 6. Average Positive and Negative Affect Score Before and After Simulation. The error bars represent 95% confidence intervals.



3.4 Observed vs. Recalled Self-Report of Behavioral Responses

After participants completed the simulation, 63.6 % reported their behavior as running towards an exit, 19.7 % reported running outside the cafeteria to hide, 11.8 % reported hiding somewhere inside the cafeteria, and 5.0 % reported standing still and not trying to hide. Figure 7 summarizes the difference between observed and self-reported behavior in the simulation. Additionally, only 40.5 % of participants reported that the actions of the NPCs influenced their behavior. Only about a quarter of participants reported ever receiving active shooter training, with only about 40.0 % reporting that they followed the training. Of the participants who received active shooter training, 61.8 % evacuated from the school, which is very similar to the 61.6 % of participants who had never received active shooter training but still evacuated from the school.

Figure 7. Percent of Participant's Most Common Observed and Self-reported Behavior

4. DISCUSSION

4.1 Observed Participant Behavior

Despite running away being the most common behavior in our simulation, manipulating social influence significantly affected response behavior. Furthermore, this effect was most potent in high- and medium-threat uncertainty conditions where participants could hear the gunshots; therefore, the NPCs would begin running or hiding before the participant could see the shooter. About 40% of participants believed the NPCs influenced their behavior, similar to the change in behavior between the run and hide social influence conditions. Similarly, participants' self-reported behavior was similar to the observed behavior constructed from the movement data in the simulation. This result suggests that participants were generally aware of their chosen behavior and whether or not others around them influenced their behavior.

Additionally, female participants were significantly more likely to hide compared to males. Why this occurred is beyond the scope of this study but merits future consideration for understanding behavior in response to an active shooter. There were no significant main effects for threat uncertainty, suggesting participants' behavior did not depend on the location of the threat. Instead, once a threat was identified, participants either ran away or attempted to hide, with their likelihood of choosing either option influenced by what others around them did and their gender.

4.2 Decision to Evacuate

In seven of the nine conditions, most participants evacuated the school before the simulation timed out. Current school shooting protocol (FBI, 2022) encourages individuals to always run away if possible. Hiding is considered a backup option if running away is not possible, and attempting to fight the shooter should be a last resort. However, when the threat uncertainty was high or medium, and the NPCs hid in our simulation, most participants decided not to leave the school. In contrast, 7-15% more participants ran away when the threat uncertainty was low (the shooter started in the same room), and participants understood that hiding might not be the safest option. Significantly, more participants evacuated in the run social influence condition compared to the hide. Males were significantly more likely to evacuate than females, which may be based on their belief that they had a higher chance of running away from the shooter, but further research is needed. While current safety protocols emphasize running away as the preferred option, individuals may not want to risk attempting to run away just to end up in the shooter's path. Our results indicate that when the uncertainty of the threat is low and if they are male, participants are more likely to run away when others attempt to run away.

4.3 Participant Response to Simulation

Participants indicated a significant decrease in their positive affect and a significant increase in their negative affect after playing the simulation. Despite the virtual environment, in which participants could not be physically harmed, the change in affect suggests the simulation was realistic enough to elicit an emotional response. The distribution of participants' self-reported behavior was similar to observed participant behavior across all conditions. Notably, approximately 5% of participants indicated standing still and not trying to hide. Since all participants had to complete the training within the time limit, these participants could move their character during the data collection section. Instead, it is likely that these participants may have panicked after hearing the gunshots and experienced hesitation about whether they should run away or attempt to hide. Interestingly, the percentage of participants who evacuated was the same based on whether or not they had ever received training. This is in contrast to Liu et al. (2023), who found that participants who watched a training video immediately before the simulation were more likely to follow the recommended evacuation protocol instead of following NPCs in the simulation. This implies that training is primarily effective when recent, specific to the location/building, or a combination of both. Whether this suggests their prior active shooter training was not recent/memorable enough or that participants were not familiar enough with the building and decided to follow the NPCs is a topic that deserves further research.

5. CONCLUSION

The results of our simulation indicate that the decision to run away or hide from a school shooting is impacted by what others around an individual are doing. Participants were more likely to run away when the NPCs ran and more likely to hide when the NPCs hid. Furthermore, this effect is stronger when the uncertainty of the threat is higher. When the uncertainty of the threat is low, participants are less likely to be influenced by others and instead appear to react instinctively to the threat. Participants were typically aware of the behavior they chose and whether or not the NPCs influenced them. Participants also exhibited an increase in negative affect and a decrease in positive affect following the simulation.

Acknowledgments

This material is based upon work supported by the U.S. Department of Homeland Security under [Grant Award 22STESE00001-02-00]. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security. This award was made to Northeastern University and the University of Southern California is a sub-awardee. We also thank Burçin Becerik-Gerber and Gale Lucas's teams at the University. of Southern California for providing a school environment which we modified for our experiments. Finally we thank Gensler for developing the building architecture in the simulation.

References

Arteaga, C., Park, J., Morris, B. T., & Sharma, S. (2023). Effect of trained evacuation leaders on victims safety during an active shooter incident. *Safety Science, 158*, 105967.

Awada, M., Zhu, R., Becerik-Gerber, B., Lucas, G., & Southers, E. (2021). An integrated emotional and physiological assessment for VR-based active shooter incident experiments. *Advanced Engineering Informatics, 47*, 101227.

Bahmani, H., Ao, Y., Yang, D., & Wang, D. (2023). Students' evacuation behavior during an emergency at schools: A systematic literature review. *International Journal of Disaster Risk Reduction, 87*, 103584.

Bott, R. E. (2021). Using reinforcement learning for active shooter mitigation (Doctoral dissertation, Purdue University).

Douglas, B. D., Ewell, P. J., & Brauer, M. (2023). Data quality in online human-subjects research: Comparisons between MTurk, Prolific, CloudResearch, Qualtrics, and SONA. *PLOS ONE*, *18*(3), e0279720.

Drury, J., Cocking, C., & Reicher, S. (2009). The nature of collective resilience: Survivor reactions to the 2005 London bombings. *International Journal of Mass Emergencies and Disasters, 27*(1), 66-95.

Federal Bureau of Investigation (FBI). (2022). Active shooter event quick reference guide. Retrieved from [URL for FBI guide].

K-12 School Shooting Database (2024). The K-12 school shooting database. Retrieved from https://k12ssdb.org/

Liu, R., & Becerik-Gerber, B. (2022, October). Human and building digital twins for virtual reality-based building emergency training. In 2022 IEEE 2nd International Conference on Digital Twins and Parallel Intelligence (DTPI) (pp. 1-2). IEEE.

Liu, R., Zhu, R., Becerik-Gerber, B., Lucas, G. M., & Southers, E. G. (2023). Be prepared: How training and emergency type affect evacuation behaviour. Journal of Computer Assisted Learning, 39(5), 1493–1509. https://doi.org/10.1111/jcal.12812

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070.
Worthington, D. L., & Bodie, G. D. (2021). The impact of stress on listening during active shooter events. *Journal of Applied Communication Research, 49*(2), 123-143.

Zhu, R., Becerik-Gerber, B., Lin, J., & Li, N. (2023). Behavioral, data-driven, agent-based evacuation simulation for building safety design using machine learning and discrete choice models. *Advanced Engineering Informatics, 55*, 101827.

Zhu, R., Becerik-Gerber, B., Lucas, G., Southers, E., & Pynadath, D. V. (2019, June). Information requirements for virtual environments to study human-building interactions during active shooter incidents. In ASCE International Conference on Computing in Civil Engineering 2019 (pp. 188-195). Reston, VA: American Society of Civil Engineers.

Zhu, R., Lucas, G. M., Becerik-Gerber, B., & Southers, E. G. (2020). Building preparedness in response to active shooter incidents: Results of focus group interviews. *International Journal of Disaster Risk Reduction, 48*, 101617.

Zhu, R., Lucas, G. M., Becerik-Gerber, B., Southers, E. G., & Landicho, E. (2022). The impact of security countermeasures on human behavior during active shooter incidents. *Scientific Reports, 12*(1), 929.