Project Vision Zero - Virtual Reality (VR) Experiment with Elderly Pedestrians

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Introduction

Between 2017 and 2019, senior citizens accounted for, on average, 47 percent of pedestrian fatalities in New York City (NYC DOT).[1] This statistic comes as the population of older adults has grown at a rate 17 times that of the general population between 2000 and 2023, comprising 17.3 percent of the city's population (Office of the New York State Comptroller).[2] Accordingly, the overrepresentation of seniors in traffic victim data has led the city government to establish the Vision Zero Initiative in 2014, with the goal of drastically reducing preventable traffic deaths and injuries by 2024. Despite some significant success, traffic safety remains a paramount concern, particularly as New York City's population continues to age and millions of new seniors are poised to brave the streets in the coming decades. Furthermore, the cause for concern does not stop at the city's evolving demographics, as urban areas like New York have undergone what the U.K.'s Faraday Institution has branded as a micromobility revolution, where e-bikes, scooters, and mopeds become ubiquitous on our streets. A multitude of factors, including the meteoric rise of services like Lyft's Citibike and the widespread adoption of bikes for deliveries, have rendered micromobility a crucial part of urban life. Similarly, policies such as the City Council's 2020 bill legalizing e-bikes and e-scooters have been paired with congestion pricing legislation, as New York City rushes to dynamically reconfigure its streetscapes to meet society's current needs.

Concurrently, our socio-technical landscape has advanced rapidly, positioning fields such as artificial intelligence (AI) and cloud-edge computing at the forefront of engineering research. In an era with more data than ever before, and more powerful mechanisms to help researchers analyze and make sense of that data, Columbia University's Center for Smart Streetscapes (CS3) was born in 2022, aiming to "forge livable and safe communities through real-time, hyper-local streetscape applications." This summer, as student researchers at the Center's Summer Research Institute, we had the opportunity to contribute to a project deploying virtual reality (VR) technology as an assistive technology to facilitate safer and smarter active transportation, particularly in light of the aforementioned rise of micromobility. Our engineering project involved using C# code, Unity3D, and AI waypoint navigation software to create VR simulations of the COSMOS testbed at the intersection of Amsterdam Avenue and West 120th Street.[3] Furthermore, we have made use of real-time Message Queuing Telemetry Transport (MQTT) micromobility data, with a particular emphasis on e-bike/e-scooter "near-miss" trajectories, while incorporating vehicles and pedestrians to create a realistic model of a complex traffic system. This endeavor warranted a particular focus on the dynamic nature of pedestrian spatial awareness, leading us to conduct participatory research in the local Manhattanville and Central Harlem neighborhoods. This social science research involved methods including surveys, interviews, and ethnography, each of which allowed us to uniquely understand the multifaceted issues facing older community members with regard to pedestrian safety and urban mobility.

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[1] Viola, S. Hostetter, A. Getman, C. Brunson, A. Gunawardana, A. Kaputkin, A. Khermouch, and J. Kite-Laidlaw, *New York City Senior Pedestrian Safety Study* (New York: New York City Department of Transportation, January 2022), 3, https://www.nyc.gov/html/dot/downloads/pdf/pedestrian-safety-older-new-yorkers.pdf.

[2] Office of the New York State Comptroller, *Older Adults in New York City: Demographic and Service Trends*, Report 22-2025 (Albany, NY: Office of the New York State Comptroller, January 2025), 2, https://www.osc.ny.gov/files/press/pdf/report-22-2025.pdf.

[3] COSMOS stands for Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment.

Our initial findings helped direct our research toward challenges among older pedestrians precipitated by micromobility. Accordingly, we weaved the photovoice method with existing qualitative and quantitative data from surveys, interviews, and ethnographic research. Essentially, engaging stakeholders through the aforementioned methods enabled us to add a dimension to our engineering research, informing our culminating goal of designing a visual warning feature that detects oncoming micromobility traffic, as we strive to promote safer streetscapes.

Methods & Results

Research Design and Methods

During our research, we conducted two rounds of data collection in the local community to gain a deeper understanding of elderly citizens' concerns, and perspectives regarding pedestrian safety and the deployment of VR to enhance spatial awareness, particularly in the context of the "micromobility revolution."

During our first research trip, we primarily focused our efforts on ethnographic research, which entailed conducting interviews and making detailed observations of the local community. The template for these initial interviews can be found under Appendix A, and we designed our interviews with the aim of capturing nuanced qualitative data. We anticipated that our open-ended set of questions would enable participants to communicate more general sentiments while also highlighting certain anecdotal details and narratives, each of which would help to guide subsequent inquiry. These initial interviews were very much exploratory in nature, and particularly valuable to us when paired with ethnographic observations. In these observations, we paid particular attention to intersections, traffic patterns, and how Harlem community members interacted with these systems. Examples of factors we scrutinized range from signage configurations to the interactions between micromobility, trucks, and pedestrians. This plethora of qualitative data allowed us to further focus our methods in subsequent field work, where we aspired to gather complementary, and slightly more targeted, quantitative data.

Our surveys were designed to gather quantitative data on participant comfort levels when navigating local streetscapes. These surveys were less conversational than our earlier interviews, since we strove to collect specific data for each of the four prompts outlined in Appendix B. We also designed our survey such that responses were quantifiable using a Likert scale. This method saw us design questionnaires where converting between an answer such as "somewhat disagree" and a 2 (on a 1-5 scale, 5 being the strongest answer) was seamless. This ability to easily convert between quantifiable data and tangible insights was invaluable to us in our analyses. Our quantitative data collection through surveys centered on two principal topics, to which our previous research had led us. The first such topic was spatial awareness in Harlem intersections, with a specific focus on the impacts of e-bikes, scooters, and a plethora of other vehicles/mobility. The second such focus asked questions to gauge VR familiarity and ultimately, how willing participants would be to participate in a free pilot study.

In addition to the methods above, our group also conducted additional field work focused on capturing images for an upcoming photovoice exhibit. Photovoice is a method that aims to weave photographic data with compelling and accessible narratives. We sought to focus our photo curation on moments concerning issues of pedestrian safety and micromobility, which would bring a unique set of insights to our existing research.

Aims/Goals

We aimed to cultivate our research such that it would address the following primary research question: *how can VR be effectively implemented as an assistive technology to facilitate safer, smarter, and more comfortable active transport*? Given the research our mentors and others have already done on the feasibility of VR as an assistive technology, we sought to understand how this technology could be piloted to effectively promote pedestrian safety. Accordingly, we put particular effort into identifying the specific issues hindering pedestrian spatial awareness. With a knowledge of these issues, we would then explore and engineer prospective features that could help to address the most prevalent issues facing elderly community members. To achieve this goal, it was necessary to collect data on each of the following: pedestrian safety perceptions, specific hindrances to situational awareness, VR technology knowledge, and participant willingness to try such technology. To collect this data, we leveraged both qualitative and quantitative research methods, with ethnography being particularly important to achieving our goals.

Initially, we hypothesized that participants would cite – at least in some capacity – the impact of various modes of micromobility, alongside a frustration with drivers. We also posited that some would mention specific policy actions that may have made an impact locally. Another theory that had merit was the concept that generational divides played a role in technology exposure; senior citizens would often have limited technology exposure and thus, little familiarity with VR. The existing project template in the Unity3D software already contained a virtual rendering of the intersection. However, given our newfound insights into community needs, our main goal was to add features into our simulation that would be effective in addressing these needs. Some of these engineering features built based on participant research input included synchronized moving cars, pedestrians, micromobility, along with a collision warning system optimized for e-bikes and e-scooters. By pairing our social science research with engineering development, we aimed to successfully turn data into pinpointed insights, which in turn would create a final product that meets the community's needs.

Research Protocol

On our first trip, we executed our ethnography and interview procedures detailed in "research design and methods" in two local neighborhoods: Manhattanville and Central Harlem. These neighborhoods were initially selected due to their respective proximity to Columbia's Innovation Hub and most importantly, the anticipated high levels of pedestrian and vehicle traffic. We conducted ethnographic research at 125th Street, starting on Broadway and continuing eastward. The initial encounters we had eventually led us to use the southeast corner of 125th Street and Amsterdam Avenue, which served as the primary location for our first segment of the data collection process. There was a brief period that saw us venture south on Amsterdam Avenue, but never further than 123rd Street, remaining in the same neighborhood. Beyond the ethnographic research we did on Amsterdam Avenue, we also briefly executed our research agenda in the western part of Central Harlem on 125th Street between St. Nicholas Avenue and Frederick Douglass Boulevard. As per the method design, our interview questions served as the framework for genuine conversations where participants could expand freely on any opinions or concerns with regard to both pedestrian safety and VR implementation. The interview protocol was largely successful in gathering qualitative data that was relevant to our overarching research question. The implementation of methods was also successful in the sense that it highlighted new unforeseen details, such as the danger presented by Amazon E-bikes, or the confusing arrangement of traffic lights/signage. Given the insights from this first round of interviews, we were able to further focus our methodology for the second research trip.

For our second trip, we refined our survey questions from the original set that predated even our first trip (see Appendices A & B).We simplified our survey protocol based on interview feedback we received, since our priority was now gathering precise quantitative responses from our participants. This adjustment allowed us to build on what we learned from the interviews, while collecting data from a larger sample of people. This quantitative data was also ideal for analysis and easy to visualize. Using a Likert scale we had designed, we administered our survey on a scale of 1-5 (instead of the more complex 1-10 we had originally devised), and assigned a qualitative conversion for each numerical data point. We chose to use a 1-5 scale to streamline our questions and simplify the experience of respondents. Part of our protocol for trip two also included a round of peer review, which helped us cut unnecessary questions from our initial survey draft. Our new survey was now ready to be an integral component of our research process, and we brought this tool into the community.

We chose to return to the intersection of 125th Street and Amsterdam for our second trip, as its proximity to multiple bus stops, a senior care facility, and high amounts of foot traffic resulted in many successful interviews during our first excursion. However, during our time at the site for the second visit, we did not have as much success finding willing participants, as responses were scarce at best. We subsequently relocated our base to 125th Street and Frederick Douglass Boulevard. This change was recommended by another research group in our cohort for its high amount of foot traffic and proximity to malls, food shops, train stations, and bus stops, which would hopefully result in better data.

Overall, our two research trips were similar, but differed slightly in how and what we asked our participants. The first trip focused on gathering in-depth personal accounts from elderly citizens to grasp an idea of the issues that are most pressing to their safety while crossing the street. The second trip narrowed on the issues that were pointed out in the previous interviews, and used surveys to gather qualitative data, with the stated goal of understanding the magnitude of such issues..

Data

As we mentioned in our introduction and research design and methods sections, we collected multidimensional data through surveys, interviews, and ethnographic observation in Harlem. All participants were approximately 60 years or older,[4] and we collected data from participants who were both local residents and members of other communities, since they all had experience traversing Harlem's intersections. Demographic data, including, but not limited to, factors such as gender, ethnicity, and occupation, were only collected if participants volunteered this

[4] Senior citizen is generally used with respect to individuals 65 and older, and our decision to interview individuals 60 and older was made with full knowledge of this. We chose to broaden our target demographic slightly based on the potential to gather higher-quality data that would still yield similar insights for our research.

information.[5] We did not collect such data points since our aim was to gauge pedestrian sentiments on a broader scale, without necessarily stratifying by other demographic indicators. If we had decided to include such questions, parts of the data collection process could have become slightly uncomfortable for participants, potentially decreasing the efficacy of our core research design.

The qualitative portion of our data collection produced an array of experiences, views, and strong opinions. For example, even when many personally felt safe as pedestrians who take necessary precautions, participants often expressed concern for afflicted loved ones and friends, stressing certain geographic locations. Similarly, a prevailing sentiment among participants was that “even older” vulnerable pedestrians and non-Harlem residents would be best positioned to reap the benefits of assistive VR technology.

Our first qualitative-oriented encounter took place at a Con Edison construction site under the 1 train track, at the intersection of Broadway and 125th Street. There, we noticed a woman carrying a shopping cart across wet asphalt, where construction barricades significantly obstructed the designated crosswalk, thus impeding active transportation. She walked in the middle of the road, remaining stranded there even when the light changed and cars began to pass by the crosswalk. Despite thinking that she was in a perilous situation, she nevertheless remained quite calm and maintained a constant speed. After she crossed the street, we proceeded to interview her, an experience that confirmed her calm and composed attitude. When we asked how safe she felt when crossing streets, she confidently asserted that she felt safe – a perspective that stood in direct contrast to what our observations had indicated to us. This perspective illuminated the common gap that often existed between one’s lived experience and our outside perception of the same situations. In other words, navigating traffic scenarios that we perceived as hazardous could have easily been trivial everyday affairs for a longtime local resident.

Both qualitative interviews and quantitative surveys brought out great enthusiasm in participants, transforming scripted prompts into detailed personal stories, and in turn, producing tangible insights for our engineering design process. One such experience was an interaction with Interviewee 2. When we questioned this man on his comfort level when navigating intersections in Harlem, he voiced his frustration at a recent rise in excess traffic on 125th Street which he attributed to the newly implemented congestion pricing: “Now [vehicles and trucks] try to come towards the bridge and all up on this street. And our parking spaces! And at times I’m trying to chill about here and I can't even find a parking space because that’s where all the people [are] at.” His candid and thorough response provided invaluable insight into an issue for which a traditional survey would often fail to account; we also failed to anticipate this specific yet crucial nuance. Interviewee 2 continued with an experience of his at the intersection of 125th Street and Morningside Avenue, just a block away from where we were speaking. “As soon as I stepped out from the street, I stepped into the street, I [gestured] the truck to stop, and they told me to go ahead. As soon as I passed the truck stopped at the [intersection], [the bike] came down right between and hit me.” Although few had experience as dramatic as that of Interviewee 2, many echoed similar feelings of discomfort and a particular concern with urban safety in streetscapes that are increasingly dominated by bicycles. In another instance, a man who we will name as ‘Queens’ (as he lived in Astoria) shared the new safety measures he has taken in the age of

[5] We did collect age-range to ensure that these individuals could be included within our sample. However, we did not collect exact age data unless participants explicitly volunteered this information, in which case we made note of it. We did not include age in our data presentations, given that our goal was to gauge pedestrian sentiments on a broader scale.

electronic micromobility: “Scooters and e-bikes are not as visible. So I'm way more careful now when I cross the street. I don't jaywalk anymore. I used to jaywalk in New York. I no longer do it. I wait for the signal. Then still look both ways.” Stories like the one Queens detailed to us directly shaped the concerns we aimed to address in our immersive complex traffic simulation. Moreover, pinpointing electric micromobility as a preeminent pedestrian issue in the Harlem community deeply influenced how we developed new software features such as the bike blind-spot warning system based on near-miss trajectory data.

Beyond micromobility, a plurality of participants shared a specific concern about the confusing configuration of traffic signals at the intersection of 125th Street and Amsterdam Avenue. Interviewee 2, for example, explained how the traffic signals confused drivers and directly exposed pedestrians to unnecessary danger: “So a lot of people don't know there's an arrow on that light…an arrow on that light for that turn to go that way. [Drivers] break it and they come across and they cut on these people that's turning right here and we across the street right here [and] they cut us off. And we’re stuck in the middle.” This instance was useful to both our ethnographic inquiry and photovoice, as we photographically documented this confusing arrangement of signals and extensively observed the intersection. The same problem resurfaced in an interview with ‘Bus Woman,’ a woman we met next to the bus stop on the east side of Amsterdam Avenue between 124th and 125th Streets, who shared her concern over reckless drivers. In noting the turning traffic light at this intersection, Bus Woman exclaimed, “...[S]ee how the light came, come in and people don't pay that light no mind…that third lane can go and people don't pay it no mind.” Bus Woman's commentary presented another unique perspective, which saw her place the blame with drivers rather than the traffic light configuration itself. This frustration with recklessness on the part of drivers and cyclists (and a perceived lack of traffic safety enforcement) was quite common. Prior to this field research, traffic signals had not been a major focus of our research, yet our data indicated that they perhaps should have been. We learned that confusing signage played a significant role in shaping perceptions of pedestrian safety in Harlem, and accordingly sought to make accessible and explicit signage an integral part of our simulation, in our bid to enhance pedestrian safety.

We complemented these findings with quantitative insights from surveying the community, and our results are detailed in the remainder of this section. Below, we have briefly contextualized and analyzed our data, while also highlighting the key insights we will further discuss in the “discussion” section.

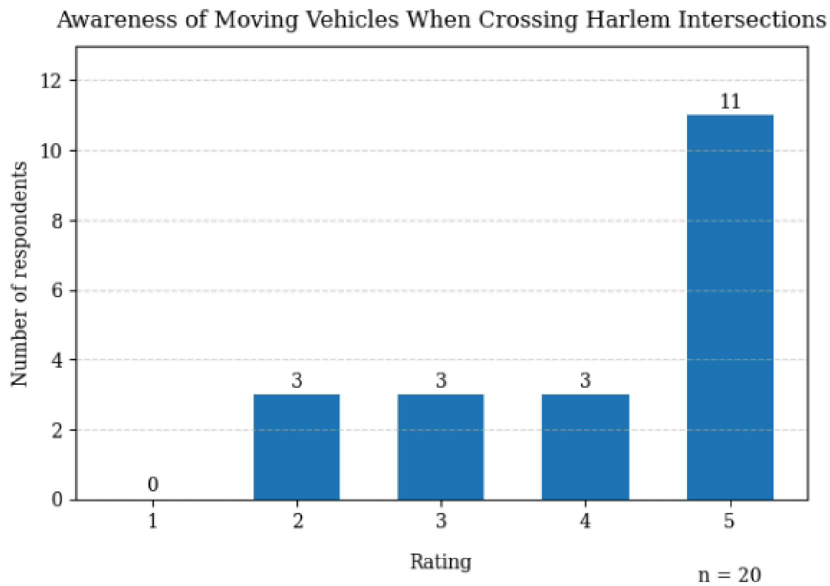

Figure A

The first of our four questions asked 20 respondents to rate their awareness of moving vehicles when crossing intersections in the local Harlem area, to which we received higher answers than we anticipated. To preface, our Likert scale was numbered as follows: 1 – "not aware at all," 2 – "slightly aware," 3 – "moderately aware," 4 – "very aware," and 5 – "extremely aware." Figure A shows that respondents tended to rate their awareness of moving vehicles quite highly. The average rating given by participants was 4.10 while the median rating was a 5.00, indicating a high confidence level in spatial awareness among our participants from the Harlem streetscape. There were 6 individuals who rated their awareness either a 2 or 3, but everyone else either characterized themselves as "very aware"or "extremely aware." Given the self-reporting nature of our survey, this question is more a measure of perceived awareness and attention, than it is an objective reflection of "true" spatial awareness. The key distinction here is that our participants were likely characterizing how vigilant they perceived themselves to be when navigating intersections in West Harlem, and the level of caution they exercised when navigating the community. The left-skewed histogram of ratings is a clear indication of the aforementioned sentiment, where participants frequently cited heightened levels of awareness in response to perceived risk.

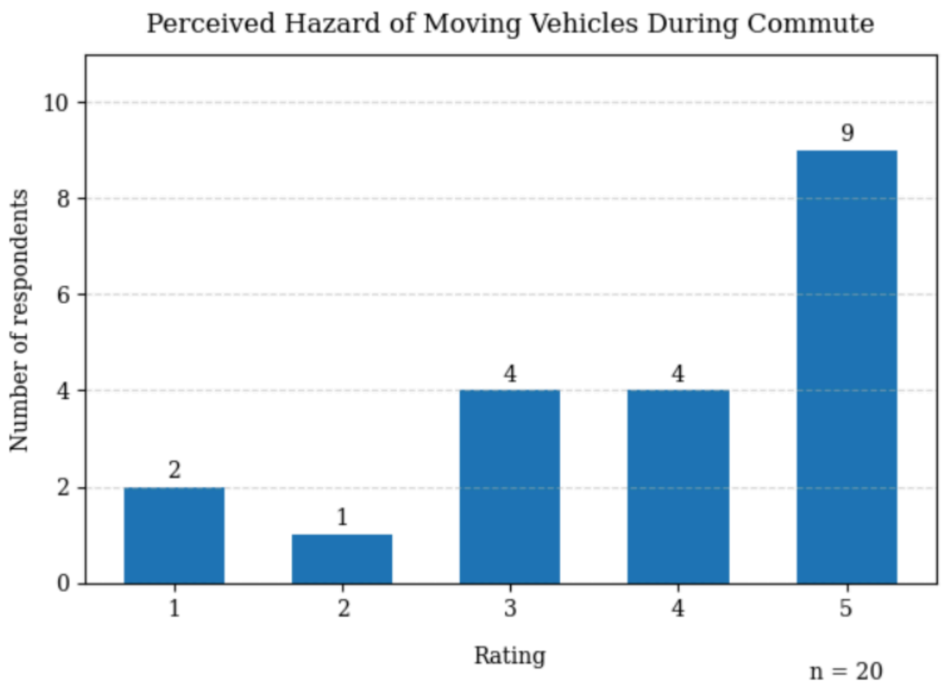

Figure B

The second of our four questions asked our 20 participants about their perceived hazard level from moving vehicles when commuting and navigating local streets. For this question, we defined "moving vehicles" to include cars, bikes, scooters, and mopeds. For this prompt, we again designed a five-point Likert scale, with the five coded responses being: 1 – "not a hazard at all," 2 – "a minor hazard," 3 – "a moderate hazard," 4 – "a pretty serious hazard," and 5 – "extreme hazard." For this question, the average response was a 3.85 while the median stood at 4.00, meaning that the majority of respondents perceived moving vehicles—especially micromobility—to be "a pretty serious hazard" to their safety as pedestrians in the Manhattanville and Central Harlem communities. There was, however, some variance in how respondents answered, with two specifically saying that they felt as if incoming vehicles were not a hazard whatsoever. There are a variety of factors that we did not measure that could have played a role here, including specific disabilities, conditions, or even older age within the sample. Our distribution once again was strongly left-skewed, indicating that participants deemed vehicles a significant hazard on multiple levels. Though we did not observe any notable collisions or accidents, we did bear witness to many near-miss incidents, which supported elevated levels of local concern. For instance, bikes would weave through turning buses at multi-way intersections, leaving pedestrians exposed to oncoming traffic. This trend was particularly common in intersections where an increased number of environmental variables were present, with an example being how bikes would often turn into narrow spaces crowded by commercial vehicles near construction sites. This observation was confirmed by two of our participants, one of whom emphatically highlighted that "they [bikes] weave in traffic."

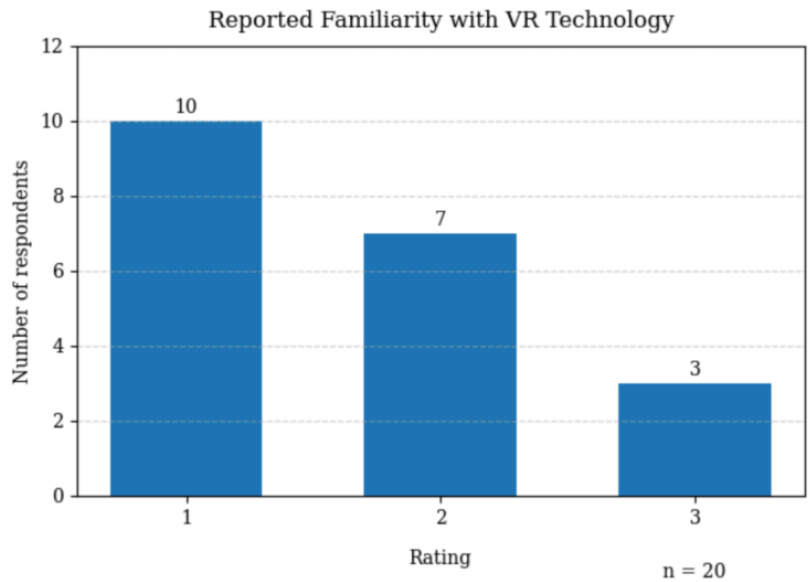

Figure C

Our third question gauged participants' reported familiarity with virtual reality knowledge of such technology. Our Likert scale is detailed as follows: 1 – "none," 2 – "little," 3 – "basic understanding," 4 – "fairly knowledgeable," and 5 – "expert." This survey question confirmed to us that the local senior community was, for the most part, quite unfamiliar with VR technology. The average here was a mere 1.65 rating while the median was 1.50, indicating that those whom we sampled tended to classify their VR knowledge as "little to none." To extract insights around VR research from respondents (see Appendix B and "methods" sections for additional details), we needed to deliver a general description of our project and frequently integrate visuals. Among nearly every participant, there was some initial level of confusion, which meant that our images and visual infographics were crucial to our study's efficacy. Responses frequently resembled one of the following reactions: "Oh, no, I haven't seen it. [This is] the first time I've seen [it];" "I've seen/heard of [VR goggles] before;" or even "I've tried [VR goggles] on a couple of times." There were, however, a few exceptions to this relative lack of familiarity, including a 75 year-old woman who had worked in the technology industry, and thus felt she had a "basic understanding" of VR. Aside from such cases, though, the array of survey data question three produced can be summed up by the words of Interviewee 10, who said: "This [VR] is hard. This [VR] is new. I'm the old-fashioned person. With hard tech things, older people are not tech-savvy."

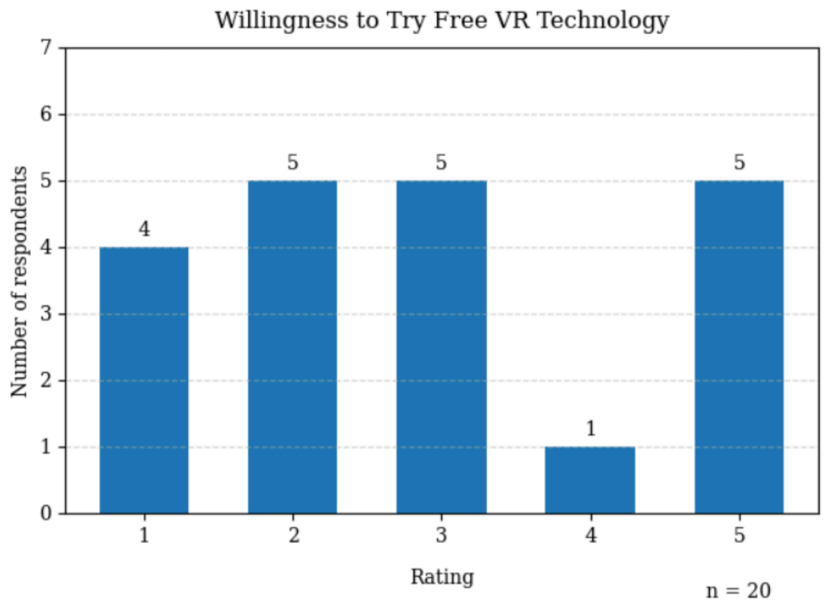

Figure D

The last of our four survey questions yielded unexpected responses, as we collected data to measure participants' willingness to try free VR technology. For this question, our Likert scale was numbered as follows: 1 – "completely unwilling," 2 – "unlikely," 3 – "neutral," 4 – "somewhat willing," and 5 – "eager." The mean rating was 2.90 and the median was 3.00, but these statistics could potentially be misleading given their inability to capture the polarization of responses. For every person who was eager to try such technology, there was at least one other person who was "completely unwilling" to do the same. Nearly half of respondents (45 percent) characterized themselves as at least somewhat reluctant to try free VR technology, rating themselves as either "completely unwilling" or "unlikely" to try VR. We did not anticipate VR creating such a divide among our respondents, yet these results became clearer when we recalled certain nuances from our interviews. Virtual reality could be a symbol of broader generational technological gaps, where many feel uneasy. Beyond these data points, many cited factors like claustrophobia and concerns about dizziness as the rationale behind their hesitancy to engage with VR. We also found an intriguing positive association between reported familiarity with VR technology and willingness to participate in such a trial, which we explore in greater depth in the discussion section. Regardless, our results highlight the need to implement VR in a gradual and respectful way that prioritizes exposure and education over immediate adoption.

Limitations

Despite our initial confidence in the research methods we deployed, our fieldwork did not come without its challenges. First, the nature of a survey administered by high school students differs greatly from many comparable academic surveys, where participants answer in a more private setting. Even though we were explicit in promising confidentiality and anonymity to participants, many may have still been reluctant to always provide earnest answers. In fact, the term "survey" seemed to connote something more negative than our earlier "friendly, exploratory interviews," the former evoking cynical attitudes from prospective participants. The population of locals seemed to question survey requests and were somewhat wary of organizations collecting data in the community. This limitation to our data sourcing may have been rooted in previous experiences, which likely engendered widespread resentment and reluctance to participate. Nonetheless, we managed to gather enough data points to analyze macro-level trends and draw concrete conclusions.

Another limitation we encountered was that we did not ultimately have an opportunity to test our VR features in a formal trial deploying our user interface. Our research process initially included a VR pilot demonstration at a local senior center, alongside our faculty advisor and mentors. However, logistical conflicts meant that our planned demonstration did not come to fruition during our tenure in the summer research cohort. The absence of such data did limit our ability to truly gauge the feasibility of implementing our VR technology in the local community. In other words, even with extremely accurate data from surveyed, interviewed, and observed participants, our theoretical inferences would not have been able to replicate the practical knowledge we would have gained from a demonstration.

Discussion

Through the responses and data we gathered on our first trip, we identified several throughlines and common narratives. One such topic that arose in our conversations was the importance of crossing streets gingerly. By this, we mean that many stressed the importance of looking both ways before and during crossing, exercising heightened caution of micromobility in blind spots, and resisting the urge to jaywalk. Because the survey was conducted face-to-face, many participants may have felt pressured to present their abilities more confidently than they actually were. This could explain why the claimed high levels of spatial awareness contrasted sharply with our ethnographic observations. In these observations, we frequently witnessed a lackadaisical level of awareness among pedestrians, with older individuals struggling to beat the countdown clock on crossing signals, often veering from the curb and boundaries of the crosswalk.

Another common theme we gleaned from interviews related to how useful participants believed VR technology would be in the context of urban mobility. Although many participants shared that they did not personally feel unsafe, those who stayed for longer interviews believed that VR held the potential to be beneficial, providing us with anecdotes of personal or secondhand experiences with hazardous situations. Many who stayed for shorter interviews and surveys also frequently signaled a general approval toward an exploratory roll-out of VR situational awareness training, stressing factors like the importance of it being free and a genuine desire to improve situational awareness due to conditions like glaucoma.[6] However, there was a significant minority among interviewed participants from our first trip[7] who expressed that they would be uncomfortable with screens that close to their face as well as generally skeptical that a technology-driven solution would ensure pedestrian safety in a tangible way.

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[6] The importance of cost accessibility was stressed across interviews–particularly by the “Dog Woman” who we interviewed between Broadway and Amsterdam Ave on 125th Street–and the glaucoma condition was cited specifically by Interviewee 2, whom we interviewed at the southwest corner of 125th Street and Amsterdam Avenue in front of the Grant Houses.

[7] Does not include surveyed respondents who gave quantitative data, which has already been presented and will be further discussed.

Other unforeseen topics that arose in our qualitative data collection included congestion pricing, VR training potentially easing street anxiety, confusing configuration and proximity of traffic lights, and Amazon quad bikes. Though these topics were not repeatedly raised, we noticed that each concern was connected; in other words, streetscapes were becoming increasingly complex and difficult to navigate for older pedestrians. The 125th Street intersection is a congested corridor, where suppliers and logistics companies transfer shipments from trucks to micromobility. The confusing intersection traffic light configuration was said to exacerbate such congestion, particularly as commercial drivers may not be as accustomed to the densely populated environment of Harlem or specific local road laws such as “no right on red.”

Additionally, micromobility use has also increased greatly in New York City, as biking and scooter systems have experienced unprecedented growth in recent years. Beyond personal transportation uses, the adoption of quad bikes by logistics platforms, coupled with the growth of food and restaurant delivery platforms, has meant that the city’s bike lanes have become more crowded than ever. This increasingly complex and hazardous set of circumstances that one must navigate – created by both vehicles and micromobility – has engendered newfound levels of anxiety and unease among the elderly population in Harlem.

From the data we collected, we were able to better understand the measures people took to mitigate pedestrian safety risks around them. Rather strikingly, community members consistently cited issues of micromobility as primary impediments to their quality of life when navigating streetscapes. Though cars were a highlighted issue, due to traffic light positioning and driver behavior, many older citizens with decades of local experience navigating intersections viewed these as inevitable, and felt as if they were used to such issues. The most perilous street situations detailed to us were often direct results of newer, high-frequency micromobility (particularly electric) appearing in one’s blind spot. The ubiquity of this issue led us to focus on incorporating micromobility in our VR software development to maximize impact among our target demographic of older community members. Our field research sparked a process of deep questioning on how we could help lessen near-miss incidents and more fatal accidents, as we sought to promote the well-being of elderly pedestrians, who represent the primary pedestrian demographic of traffic victims.

Another significant point from the finding above was that micromobility issues are not monolithic; issues stemmed across different rider and food delivery platforms and various types of micromobility vehicles. These issues are frequently compounded by factors including misleading wayfinding technology or confusing traffic signal sequencing. Since many elderly citizens may be unable to react as quickly or agilely as other community members, assistive smart-city technology can be a crucial aid to them and thus, an important step toward Vision Zero. An interesting finding was that many of the participants were more worried about peers even older than them than themselves, despite fitting the 60+ demographic. This sentiment was especially common among participants below the age of 70 who were without significant mobility impairments and disabilities. This finding can be attributed to the demographic shift our society has undergone, where advances in technology and medicine have facilitated longer lifetimes, and an ever-increasing proportion of society is above the age of 60.

These insights we received from participants were crucial in guiding the engineering research we conducted. For instance, instead of just inputting car traffic into our Unity3D simulation, we created a mechanism to use MQTT data to include real bike trajectories of near-miss incidents. Many participants also said that they tended to wake up earlier to avoid congestion, which led us to configure our simulation to encompass a variety of settings. We achieved this variation by combining different weather conditions as well as multiple times of day. This feature allowed us to create a user interface that provides prospective VR users with an accurate array of scenarios, given the effects such variables can have on the experiences of elderly pedestrians. There did, however, remain one significant hurdle to an implementation of our VR simulations, which was that older community members were still widely unfamiliar with the technology, as well as generally ambivalent towards the concept itself.

As mentioned in the data section of this paper, our respondents classified their knowledge levels of VR as being "little to none." Compounding this lack of familiarity was the fact that nearly half of respondents reported that they were either "completely unwilling" or "unlikely" to try VR, even when it is free and conducted in a safe, controlled environment. Upon analyzing these statistics on a deeper level using regression analysis, we found a moderate positive linear association—a Pearson correlation coefficient of approximately 0.44—between our respondents' VR knowledge and willingness to try free VR technology aimed at improving urban mobility.[8] Through our analysis, it became clear that generally—within our sample—people with greater levels of knowledge or familiarity with VR were more likely to be open to the use of VR to enhance pedestrian safety and spatial awareness. This data analysis allowed us to get to the core of what is necessary for a successful implementation of our research: disseminating accurate information about virtual reality so that it does not remain this elusive, expensive, inaccessible symbol of generational gaps in technology adoption. In other words, it is only once we have demystified the concept of VR and how it can be deployed as a tool to promote pedestrian safety, particularly through using real-time data amid the micromobility revolution.

Conclusion

As senior citizens still comprise nearly half of pedestrian fatalities in New York City, where they make up just over 17 percent of the population, it remains clear that our older community members are the most susceptible to increasingly intricate streetscapes, which now include vehicles, pedestrians, and micromobility. This demographic has experienced higher rates of growth than any other, meaning that efforts to enhance urban mobility are particularly of the essence, as policymakers, researchers, and others rush to implement 21st-century solutions to a problem that often evokes feelings of helplessness among its victims. Any solution to these longstanding hazards needs to represent the interests of our elderly citizens, and given our role as student researchers aiming to integrate a relatively novel technological approach, the onus is on us to deliver. Our multimodal social science research that involved ethnography, interviews, surveys, and photovoice enabled us to shed a light on the issues plaguing the lives of older pedestrians in the Manhattanville and Harlem communities, therefore positioning us to collaborate with our mentors to innovate.

Some of the key takeaways from our research were the high level of concern with regard to micromobility, the fear that policy exacerbated issues around pedestrian safety, as well as the narrative that locals did not feel seen or heard when raising their voices. Guided by these issues, we not only created a VR simulation of the intersection at 120th Street and Amsterdam Avenue but rather, created a dynamic simulation that incorporates real-time micromobility data alongside an already-complex light configuration for cars. Our simulations, created through C# code, Unity3D software, and AI waypoint navigation packages, also introduced variables ranging from

[8] Our scatterplot with the ordinary least squares regression line is in Appendix C, and can be found as Figure E.

weather to time-of-day to accurately encapsulate the complexity of the many systems at play in local streetscapes. Most significantly, real-time micromobility trajectory MQTT data from the COSMOS testbed allowed us to add a layer of realism that directly addressed the most pertinent concern echoed by participants. Our engineering research was not the only facet of our project that the community's voice had an important role in shaping. In fact, even after developing the core of our simulation infrastructure, we ventured back into the local area to explore how our technology could be implemented effectively, with an eye toward producing tangible improvements in spatial awareness and comfort among older pedestrians. From the participants from whom we had the privilege of hearing, we learned of the importance of a deployment process—for our technology—centered around messaging, transparency, and education, as we strive to achieve the goals laid out by New York City's Vision Zero initiative. We hope that our research will be an early yet important step toward protecting our city's most susceptible demographic of pedestrians, and that CS3's streetscape technology such as VR can play a role in creating a sense of comfort and peace when our seniors climb into the bus to see their grandchildren or buy groceries. Moreover, we firmly believe our data conveys that VR as an emerging tool in urban mobility is not just feasible, but when implemented in a measured manner, holds the potential to greatly enhance spatial awareness and comfort among older pedestrians as we look for new methods to make progress toward Vision Zero.

Appendix A: Final Interview Questions

Interview Questions:

1. ***Are there any challenges you face while navigating through city streets?***
    - Have these challenges always affected you negatively?
    - How has the frequency of these issues changed?
    - Are there any problems specifically in this community/intersection/hyperlocal?

2. ***What safety measures do you already take when you go outside to minimize these challenges? (frame as a follow up to 1)***
    - What precautions do you want to take but don't exist?
    - How much do these precautions affect your decision-making every day?
    - How often do you end up taking these safety precautions?

3. ***(A) Show an image of virtual reality technology on a person's face, then show a sample rendering of an intersection from VR (supplement verbally) to introduce it or perhaps ring a bell for some.***

    (B) ***Are you comfortable using Virtual Reality devices (in general & for transportation)?***

4. ***Do you think this technology would help you be more aware of your surroundings (eg. traffic, people, bikers)?***

5. ***What would motivate you to test out Virtual Reality devices for street safety?***
    - Any specific features
    - New street safety implementations

Appendix B: Final Survey Questions

1. On a scale of 1 to 5, how <u>aware</u> are you of moving vehicles and your surroundings when crossing Harlem intersections?
   1 – Not at all aware
   2 – Somewhat aware
   3 – Moderately aware
   4 – Very aware
   5 – Extremely aware

2. On a scale 1 to 5, how much are moving vehicles a hazard during your commute?
   1 – Not at all a hazard
   2 – A minor hazard
   3 – A moderate hazard
   4 – A pretty serious hazard
   5 – Extremely hazardous

3. How would you rate your knowledge of VR technology?
   1 — None
   2 — Very little
   3 — Basic understanding
   4 — Fairly knowledgeable
   5 — Expert level

4. On a scale of 1 to 5, how willing would <u>you</u> be to try virtual reality technology if it were free?
   a. We pose the question after having expanded upon its potential use in our project and in an urban mobility context, so that it is more targeted and less general.

   1 – Completely unwilling
   2 – Unlikely
   3 – Neutral
   4 – Somewhat willing
   5 – Eager

Appendix C: Figures

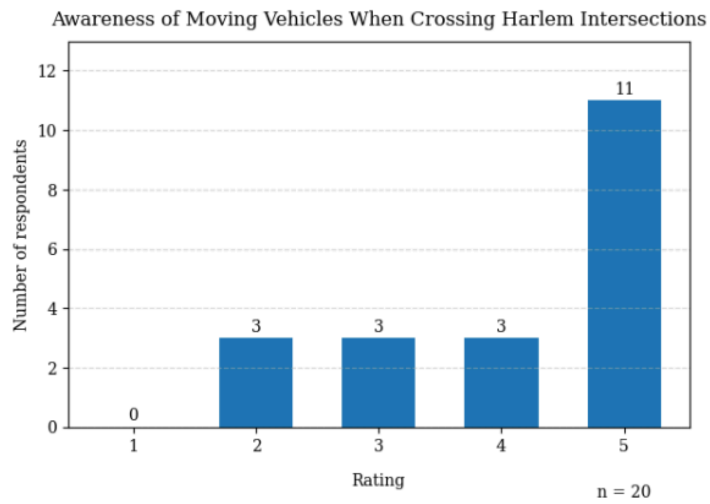

Figure A

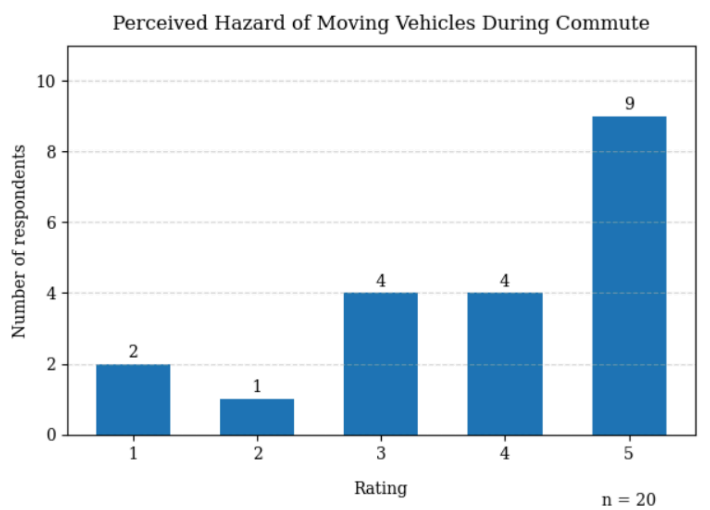

Figure B

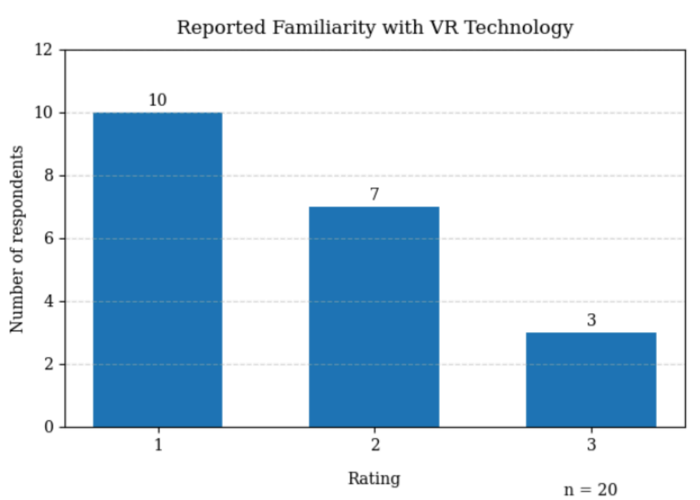

Figure C

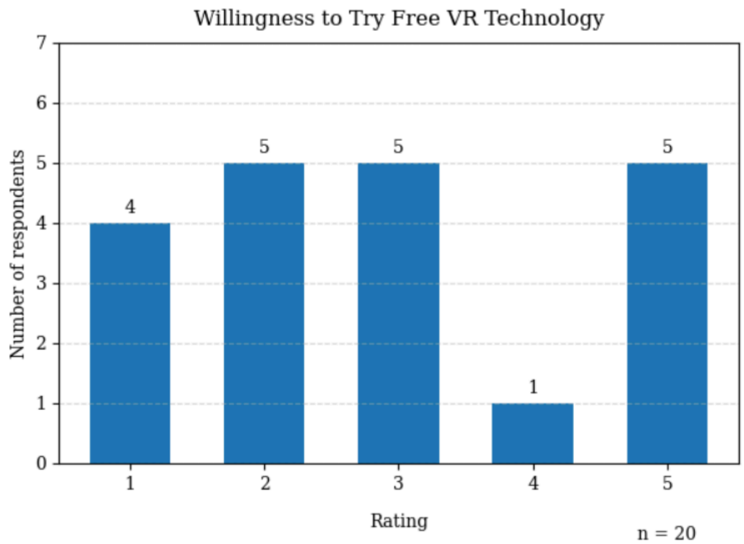

Figure D

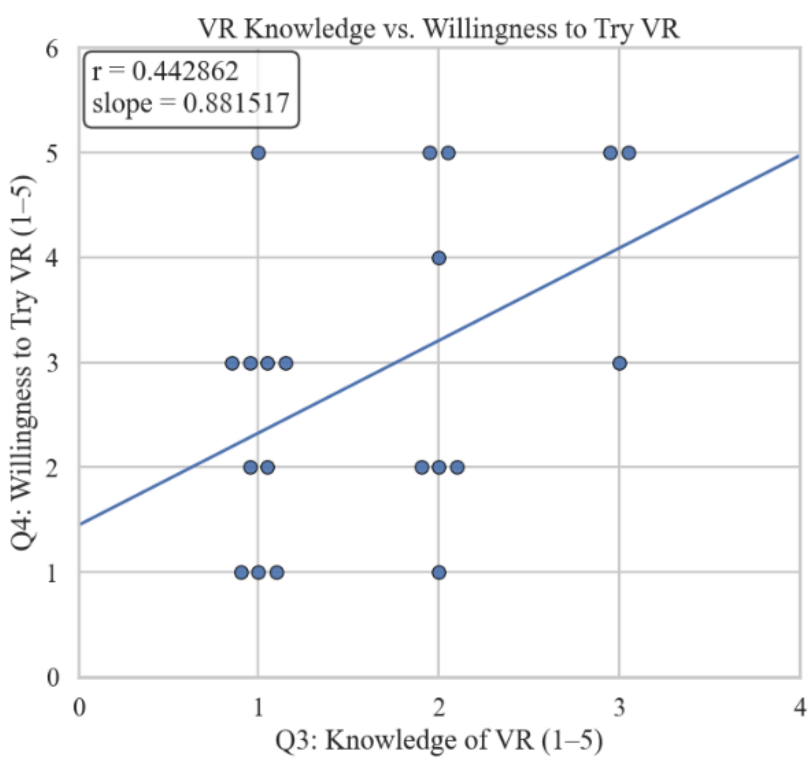

Figure E