‘I’m not alone in that battle’: Designing Immersive Visualizations for Community Awareness and Connectedness

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Community connectedness is a concept used by health practitioners and researchers to understand perceptions of: support from the community, belonging and issues, and as a protective measure for many individual health outcomes. In this paper we show how immersive visualizations presented through mobile augmented reality (AR) can be used to build community awareness and connectedness. To do so, we used a Research through Design process to develop four immersive visualizations related to mental health concerns within a local university community. We then conducted a mixed-methods field experiment to examine the visualizations' impact on participants' sense of community connectedness. We show that the visualizations increased participants' sense of community connectedness and prompted them to reflect on their relationship with the university community. We then discuss opportunities for the field of human-computer interaction (HCI) to further explore public health concepts like community connectedness and associated measures, as well as practical lessons on the design of AR and immersive visualization.

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Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

Community connectedness is a public health concept that describes the degree to which an individual feels they are supported and a part of their community [65]. An increased sense of community has been linked with positive health outcomes like decreased suicidality [63]. Connectedness has also been associated with decreased social anxiety in youth [32] and is a protective factor in traumatic experiences [85]. While public health research has examined how the concept of community connectedness can act as a protective factor for many health outcomes, we lack an understanding of how technology could be used to improve feelings of community. There is still a need to explore how emerging technologies such as immersive AR could be used for community awareness and connectedness. Human computer interaction (HCI) research offers insight into how we might design and test such a health technology. Our work combines a public health conceptual underpinning with HCI methodologies to investigate this question.

The human-computer interaction research community has recently begun to explore the concept of *immersive visualization* (e.g., [61, 30]). These visualizations seek to "remove barriers between people, their data, and the tools they use for analysis by developing more engaging, embodied analysis tools that support data understanding and decision-making everywhere and by every one" [61]. Current research is actively exploring how novel, increasingly pervasive technologies like smartphones or headsets can be used to create mixed-reality immersive visualizations (e.g., [55, 68, 77]). One "grand challenge" in the field of immersive visualization includes defining application scenarios [30], or areas where this technology could be useful to people and communities. Our work defines a new application area by investigating how mobile AR could be useful as an interactive health technology.

In this thesis, we investigate how immersive visualizations can be used to foster community connectedness. To do so, we used a research through design approach [105] to create a series of immersive visualizations that leverage public data about our local university community, focusing on mental health, chronic stressors, systemic issues and resources. We created four mobile augmented reality (AR) visualizations for a mobile device that show: (1) who is a part of the community, (2) their mental health concerns, (3) potential causes of those issues, and (4) available resources and supports. This data was communicated using 3D interactive visualizations of pie charts, timelines, and a campus map — all experienced using a personal mobile device.

We then conducted a field study in which we asked 17 participants to try the visualizations at home and assessed changes in attitudes using the Community Connectedness Scale [33]. We also administered the reflection inventory [11], the Microsoft Desirability Toolkit [10], and conducted semi-structured interviews to provide insight into participant experiences and feelings of community. We found that our visualizations increased participants' awareness of the issues and their perceived importance, and that participants felt more connected to the university community after experiencing the visualizations. Our thematic analysis [105] of interview data also revealed how the visualizations prompted participants to reflect on their relationship to the community, as well as practical issues for deploying mobile AR in the field. Ultimately, our work calls for human-computer interaction research to examine how an individuals' personal identity and role in the community can influence their experience with immersive visualization. From a public health perspective, we show that using novel technologies such as AR could be useful for public health awareness. Future work is needed, but there is compelling preliminary evidence that these types of visualizations could increase an awareness of, and/or a willingness to seek, mental health resources.

Our work has implications for both public health and human-computer interaction research. Our research through design process and immersive visualizations provide insight into how mobile AR could be used to increase community connectedness. The results of our study provide a proof-of-concept that immersive visualization can be used as a health communication tool or intervention to build community connectedness. Finally, we show how the concept of community connectedness can be used to help assess research artifacts in human-computer interaction and visualization research.

1.1 Contributions

Our contributions centre both human computer interaction and public health. This interdisciplinary work uses public health concepts to empower HCI researchers to develop community-centric technologies.

In summary we contribute:

1. a research through design approach that examines the design space of immersive visualizations and community and resulted in four visualizations on student mental health and resources,
2. the adapting of a community connectedness survey tool from public health to be used to evaluate technology in the field of human-computer interaction
3. a proof of concept that demonstrates that immersive visualizations can increase one's sense of community connectedness
4. a discussion of practical issues for mobile immersive visualization including: the role of demographic differences, navigation, and space as revealed through our field tests using participant's phones and home environment

We achieve these contributions through our research through design process. Firstly we create our visualizations and then explore how the community feels about the visualizations through field tests. We gathered many different data types to tell a complete story of how the community felt. Specifically, we collect data with the community connectedness questionnaire, the desirability toolkit, the reflection inventory and interview transcripts which we thematically analyze. We then interpret our results through a public health lens, as well as an immersive visualization lens, discussing implications for designing health interventions in AR as well as community-centric design.

In the next chapter we discuss relevant works from both public health and HCI. In Chapter 3, we present our methods and go into detail on how we conducted our research. Then Chapter 4 presents our results including the before and after of the Community Connectedness questionnaire, the reflection inventory, the desirability toolkit and the thematic analysis. Finally, we discuss the implications of our work for both HCI and public health as well as limitations.

Chapter 2

Related Works

This interdisciplinary work straddles both public health and human computer interaction. In this section, we explore important concepts in these fields to inform our research approach including: community connnectedness, interactive health technologies and immersive visualization.

2.1 Public Health Perspective

Public health informs our research in two main ways: (1) we sought to investigate if immersive visualization could influence feelings of community connectedness and (2) by interpreting our visualizations through the lens of practical challenges seen in other interactive health technologies (IHTs).

2.1.1 Community Connectedness

Public health has developed myriad ways to measure feelings of community for different applications ranging from feelings of identity [33] and perceived neighbourhood cohesion [82]. Conceptually these community measures fall broadly under the theory of the social determinants of health (SDH). SDHs are the social factors that can impact long term health outcomes [17] and include more well-known metrics such as education and socioeconomic status but also less known aspects including familial support and community factors.

Even within community survey tools, there are numerous metrics for different applications [33, 82]. Community connectedness specifically is related to the subjective feelings

of being a member of the community and shared identity [65]. While community connectedness can be defined in many ways, all definitions generally include perceptions of the community and one's personal experiences within it: bonds with other community members, pride in the community, positive experiences within the community, awareness of issues in the community [33].

Critically, community connectedness is also a *variable* factor; it can change over one's lifetime, and is therefore a pathway which policymakers and practitioners can use to improve health at the individual and population levels. Yet, we lack an understanding of the role that technology might play in moderating it — particularly in online environments like those experienced during the SARS-CoV-2 pandemic.

Because of its utility for understanding health and developing interventions, the research community has developed several measures for community connectedness. The Sense of Community Index (SCI) [56] has traditionally been used to assess community connectedness, but its utility and validity have been questioned by the psychology community (e.g., [31, 74]. In response to those questions, [23] investigated its validity in a university context and concluded that "future research investigating sense of community should use measures other than the SCI" [pg. 1]. Alternatives like the Inclusion of Community in the Self scale [62] provide a single item, pictoral, validated questionnaire to assess community connectedness at a granular level, but may not provide significant insight into *how* or *why* an individual feels connected (or not) to their community.

Work in this space has created validated scales with specific groups in mind. The Community Connectedness Scale [33] was developed specifically to understand community connectedness within the LGBT+ community. It comprises six items that assess elements of community connectedness like feeling part of a community, participating in it, and awareness of issues faced by individuals who are a part of it. The scale has also demonstrated convergent, discriminant, and predictive validity [33]. Based on these strengths, in this work we adapt the Community Connectedness Scale to understand how technology might be designed to foster community connectedness.

2.1.2 Interactive Health Technologies

Modern health communication tools like tele-health [99], or social media communication [37] can look very different from traditional public health campaigns. However, they are an important emerging area of research as more and more of life goes online, particularly in the wake of the COVID-19 pandemic. These sorts of tools are broadly classified as interactive health technologies (IHT). These technologies are widely studied for health

communication and as health interventions. This field can include research into wearable technologies [40] or technologies that promote specific health behaviours such as increasing home dialysis use [66] or increasing literacy in socioeconomically disadvantaged adolescents [89]. There are many practical challenges to deploying IHTs including how we study the evaluation of these technologies and how we study their adoption.

There does not currently exist a standardized method or survey tool for assessing IHTs. A 2020 systematic review of 42 mobile health IHTs found that most studies only used a single questionnaire (21 assessed usability, 10 assessed feasibility and 10 assessed acceptability) [47]. The authors called for the development of a standardized questionnaire for evaluating mobile health technologies [47]. Ongoing work is still needed to assess IHTs, and we contribute to the space by collecting numerous types of data and mixed methods to support a nuanced analysis of participant experience.

IHTs also face adoption challenges and it is difficult to know if an intervention will be accepted outside of the research environment. One example of difficulties in this space with regard to adoption is work by Molnar et al. who created a web-based interactive health communication application to investigate if its use would increase home dialysis use [66]. This is one of few comparative trials for IHTs, however they faced challenges with adoption and use. They found that 71.4% of participants in the group using the application had not used the website in the last month at the 1 year follow up. Difficulties with adoption are not unique to this study and are an ongoing area of research for eHealth interventions [94].

In HCI, emerging technologies such as AR are often investigated for uses in different application spaces. AR in particular has been used across numerous contexts including: education [18], marketing [3], construction [43], cultural heritage [7] and health [102]. For health AR has been used as an intervention for mental health [20], as well as to facilitate health literacy [2]. Our work investigates how augmented reality can be used in interactive health technologies.

We later reflect upon: (1) how the concept of community connectedness can be expanded for health interventions, (2) how our work fits into the IHT space and discuss how our visualizations might be adopted if we conducted a deployment in a non-research environment.

2.2 HCI Perspective

2.2.1 Immersive Visualization

The human-computer interaction research community has also explored many technologies to enable, develop, and deploy immersive visualizations. Past research has demonstrated the use of tablets and smartphones to physically explore 3D spaces (e.g., [77, 53, 83]; the use of augmented (e.g., [13, 98]) and virtual (e.g., [29, 81]) realities; and the use of novel, cross-platform authoring and prototyping tools to create visualizations [55, 84].

Recent work has sought to understand how immersive visualizations can be used to develop a sense of connectedness (e.g., [30, 61]). In pursuing this understanding, visualization researchers have coined the term 'anthropographics' [15] as "visualizations that represent data about people in a way that is intended to promote prosocial feelings" [67]. [24]. In describing the ethical dimensions of visualization research, they claim that visualizing data about people comes with an ethical imperative to anthropomorphize data. They write that "... designers may have to borrow techniques from journalism and rhetoric, and propose novel designs or interventions, in order to foster empathy and spur action using visualizations." [pg 9]. Wang el al. [96] also identify that emotion is a large part of visualization, and emphasize a need to prioritize creativity, to engage beyond the content itself, induce emotions, and to be intellectually and socially engaging. The concepts of anthropographics and connectedness form the conceptual underpinning of our work.

Despite its promise, research into immersive visualization has yet to provide comprehensive guidance for how and when it might be useful in practice. Notably, these questions align with grand challenges of immersive visualization [6, 30] — like the need to understand when it can be useful to people and communities, and how to evaluate them in those contexts. In this work, we examine mobile AR as a platform for immersive visualization visualization. Other work in this area also considers mobile AR an interesting area of research due to the fact that mobile devices are: pervasive, readily available, and portable [53]. Like other technologies, they can also integrate the real world environment with an (immersive) data visualization [83], and are therefore a useful platform to explore some of the challenges that all immersive visualizations face [30] — particularly for field studies, where participants use visualizations with equipment they already own.

In subsequent sections of the thesis we will discuss the challenges our work identified in the immersive visualizations space as well as how community connectedness can be influenced by technological intervention.

Chapter 3

Methods

To explore how immersive visualization might be used to build community connectedness we engaged in a three-stage research through design process [105] that included: (1) a Design Phase, (2) a Field Study, and (3) Data Analysis (Figure 3.1). Research through design was well-suited for this project because it enabled us to explore the complex research space of immersive visualization — including grand challenges like object placement, understanding in-situ perception and cognition, and interaction techniques [30] — while also demonstrating efficacy in health contexts [51].

We began with a *Design Phase* comprising of ideation and the technical implementation of four research prototypes, followed by pilot testing activities. These prototypes functioned as a proposal rather than a prediction [104], enabling us to explore different visualizations, to iteratively fine-tune each design, and to document that process and how different constraints shaped our design [27].

Second, we conducted a mixed-methods *Field Study* to quantify the effect of our visualizations on community connectedness and to better understand how they might be used in a home setting. Although research through design does not require formal evaluation [5], it is often used in human-computer interaction research to gain valuable feedback on prototypes (e.g., [72, 75, 36]). In our case, we chose to ask participants to use our visualizations in their homes, using their personal smartphone, to develop an understanding of their use in practice.

Finally, we performed *Data Analysis* on data collected during the field study and reflected on their implications for the design of immersive visualization and community connectedness. We performed a codebook thematic analysis [16] of interview data and pre/post

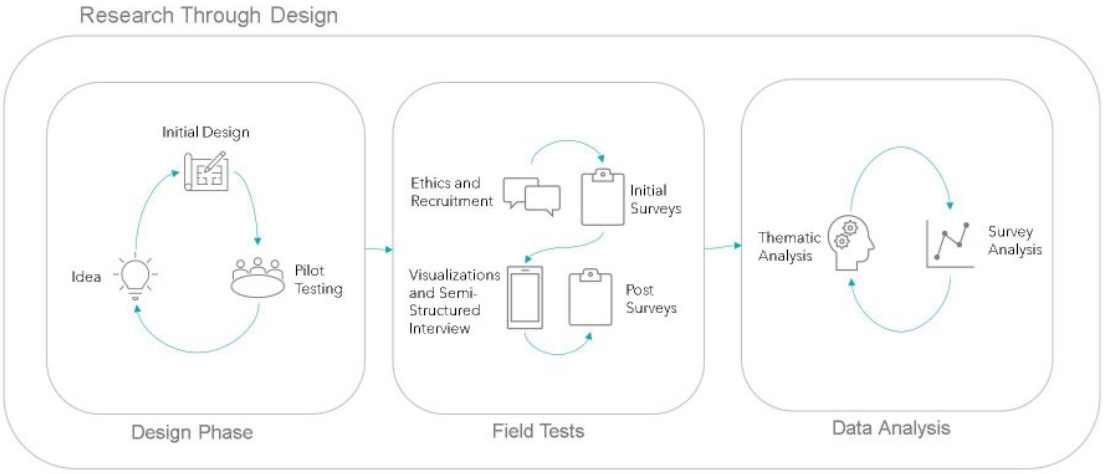


Figure 3.1: Methodological diagram of the research through design process

tests and descriptive statistics of questionnaires administered during the study. By triangulating quantitative survey data with qualitative feedback from semi-structured interviews we were able to describe how the visualizations increased participants' feelings of community connectedness, and reflect on our visualization designs, their potential utility in public health, and barriers to their use in practice.

3.1 Design Phase

To explore how immersive visualization might be used to build community connectedness, we focused on our local university community. Academic communities have been a focus of much research in community connectedness from a health perspective, because of the importance of these relationships in mediating many negative health issues (e.g., [88, 80, 28, 87]). More practically, our university community also has access to novel mixed-reality technologies and nearly all students own a personal smartphone [19], meaning that community members are well-positioned to comment on immersive visualizations using state-of-the art technologies.

Having identified the university community as our target audience, we then sought to understand how they might experience connectedness and what data might be meaningful to present to them through an immersive visualization. We settled on mental health because: it impacts everyone on campus; it has been a focus of the student population and

administration; and we had access to recent survey data from the 2019 National College Health Assessment II (NCHAII) [76]. Using this survey data, we then began an iterative conceptual design process, followed by pilot testing and technical implementation in preparation for our field study.

3.1.1 The Conceptual Design Process and Pilot Testing

We started designing our prototypes in September 2020 when our university was working remotely during the SARS-CoV-2 pandemic. At this time, mental health and connectedness were areas of concern: many were working in isolation, were in difficult family situations, and had never been in the same physical space as other students and professors. We felt that this context provided a compelling opportunity to explore how to support connectedness.

Our design process began with iterative cycles of development exploring the scope, goal and implementation of our visualizations. This resulted in four questions that our visualizations would address: (1) who is a part of the community, (2) what mental health issues exist within the community, (3) what are the potential causes of these issues, and (4) what is the community doing to address them? We decided to develop one visualization per question. For each prototype, we began by choosing appropriate data from the NCHAII to answer the question and then choosing visual metaphors to communicate that information. Each visualization went through several rounds of conceptual changes from informal feedback from lab members as we worked to find the most appropriate data and visual metaphors.

There were also ethical questions in choosing what data to represent in the visualizations. For example, the NCHAII included statistics on suicidal ideation that we actively chose to exclude from our visualizations. Although these are real data from the community, we did not think discussing this aspect of mental health would change the overall message of the data shown and could potentially be triggering. As a guiding principle, we strove to visualize mental health issues that are common in the community and likely that students encounter on a regular basis. The logic for this is that we would only be providing context and education on issues likely already experienced. Although all participants were supervised while interacting with the visualizations, we had an abundance of caution and strove to talk about the complex issue of mental health in a sensitive way that served the community.

After developing an initial set of prototypes we conducted three pilot tests with informal feedback from members of our lab to refine our design as well as test it in different locations. The researchers used the visualizations and then we did an informal interview

about improvements to the design and content. Valuable feedback was provided on adapting the visualizations to various locations, ensuring the interface worked on all phones, content and phrasing of the visualizations as well as removing ambiguity of interpretation. Although we did not evaluate the pilot tests with specific criteria, we focused on ensuring that the visualizations were interpretable, usable and understandable. This involved asking questions on if the data was understandable, the visualizations could be viewed easily as well ensuring the overall messaging was clear.

3.1.2 The Technical Design Implementation

We implemented four visualization prototypes based on our initial designs. We wanted the visualizations to work with most modern smartphones and to reflect technology that was currently available. After exploring various mobile AR toolkits we settled on Zapworks. ZapworksStudio suited our goals as it: (1) offered world-tracking mobile AR for many modern phones, (2) had an easy to use development interface, (3) allows users to scan a ZapCode (similar to a QR code) to open the visualization, and (4) is compatible with iPhone 8s and higher or Androids with ARCore support and a modern OS.

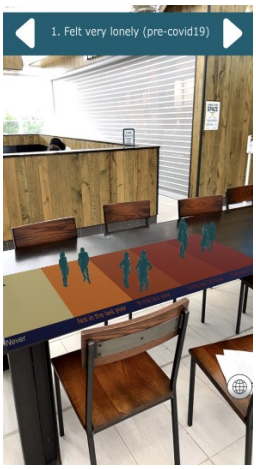
The process of making a visualization was as follows: We (1) designed the visualization on paper, (2) created or obtained 3D assets, (3) imported the assets into Zapworks, placed and animated them, and then (4) created visualization cards with a description and a ZapCode to open the visualization. Our 3D assets were primarily made using Blender, a free and open-source 3D toolkit. However, we also used the pre-fabricated 3D asset 'Lowpoly People + Waldo' created by Loïc Norgeot[1] as well as MapsModelsImporter[2] to download a 3D model from Google Maps.

3.1.3 Prototype Visualizations

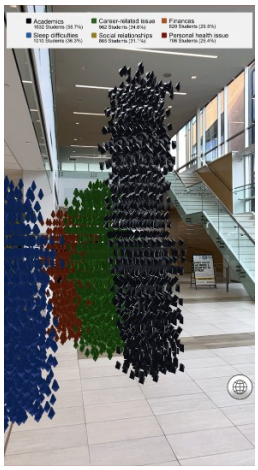
We developed four immersive visualizations using the Zappar app to explore how visualizations of community mental health data might help to build community awareness and connectedness. At the end of our design phase we had created four conceptually-linked visualizations (Figure 3.2), each addressing a different aspect of mental health on campus: (V1) the diversity of people and health needs on campus, (V2) student mental health issues, (V3) the causes of student health issues, and (V4) student resources for community and mental health. To use each visualization, a community member scans the corresponding

[1] https://sketchfab.com/3d-models/lowpoly-people-waldo-9ec7a14729aa490fa712e51c217db0f5
[2] https://github.com/eliemichel/MapsModelsImporter

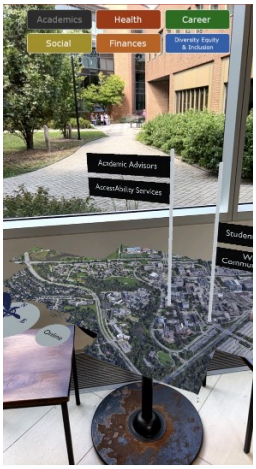
(V1) **Diversity of People and Health Needs on Campus** 3D pie charts illustrate summary demographics for students' age, sexuality, student status, ethnicity, and gender.



(V2) **Student Mental Health Issues** A visualization of frequency of responses for students experiencing anxiety and depression symptoms



(V3) **Causes of Student Issues** Stacks of 3D polygons representing students who indicated issues such as academics or finances were 'traumatic' or 'very difficult to handle'.



(V4) **Student Resources for Community and Mental Health** A 3D map of the university campus showing the location of available resources such as health or accessability services.

Figure 3.2: Screenshots of visualizations as seen by participants

ZapCode to open it on their smartphone. They then are prompted to place the visualization in their environment using floor-tracking, and then are able to explore the visualization through navigation through 3D space and buttons.

V1: Diversity of People and Health Needs on Campus

V1 aims to answer who is a part of the community through 3D pie charts showing student demographics. The 5 pie charts show age, sexuality, student status, ethnicity, and gender. The pie charts are presented in a circular layout, distributed around the viewer, and invites participants to walk around and through the charts to learn about the diversity of students and health needs present in the community.

V2: Student Mental Health Issues

V2 examines pressing mental health issues within the community. Specifically, it comprises a graph showing incidences of depression and anxiety "in the last 2 weeks", "in the last 30 days", "in the last year", "not in the last year", and "never." Note that viewers were pre-briefed that the data was all collected from before the COVID19 pandemic and this was repeated in the descriptions of the metrics. Viewers can scroll through responses to several questions relating to depression and anxiety, including: "felt overwhelmed by all you had to do", or "felt very sad." In each graph, responses are represented by silhouettes of people, in a nod to anthropographics [15]. For example, if 3 silhouettes were on the "in the last two weeks" section for "felt overwhelmed by all you had to do", it would mean 3/10 students felt overwhelmed by all they had to do in the last 2 weeks.

V3: Causes of Student Issues

V3 examines traumatic or difficult student experiences from the last year, categorized as: academics, career, finances, sleep difficulties, social relationships, and personal health issues. Each of the 2781 student responses were represented through a 3D polygon, situated around the viewer, with the intention of physically representing how many people in the community struggle with these issues.

V4. Student Resources for Community and Mental Health

V4 directs students to existing, on-campus resources using a 3D map with flags labeling where community resources can be found such as health services, academic advisors and

social activities. There is an accompanying website not linked to the AR experience that can provide details on demand for these resources, such as who can access it and what services they offer. This website mimics the interface of V4 and is designed so that participants can easily open it again without using AR. Please find the resources website: https://raywoo32.github.io/raywoo32.github.io-waterloo-resources/

3.2 Field Study

Next, we deployed our visualizations in a mixed-methods field study. Our research is community centred, so it is natural to include the community we were studying in some parts of the process. We wanted to understand how our visualizations might be experienced by real people and to develop a preliminary understanding of their effect on community. Through these tests we explore if mobile AR could be used for community public health awareness and connectedness.

Our field tests can provide real-world insight as we conducted them in community member's homes, with their personal smartphone. In total, we had 17 participants and collected both qualitative (transcripts that were thematically analyzed) as well as quantitative data (Community Connectedness Scale [33], Reflection Inventory [11], and the Microsoft Desirability Toolkit [10]). Our qualitative findings provide a rich context to our quantitative findings to create a full picture of a participant's experience. See chapter 4 for the full results of these metrics.

3.2.1 Participants

We recruited 17 participants from the university community who were fluent in English and who owned a compatible smartphone (Table 3.1). Two potential participants were excluded because they did not have a phone with the most modern version of the OS. Our final pool included: 5 men, 1 non-binary person, and 11 women. Their median age was 25 with the youngest participant being 20 and the oldest being 44. As all participants were from our local university, all had completed some amount of post-secondary education. Participants came into the experiment with varying experiences with headset and mobile AR/VR: 10 participants reported having 'no experience' and 7 reported having 'some experience'. Participants used their personal smartphones to complete the visualization tasks: 11 participants used iPhones, and 6 used Android phones (2 Google, 1 Huawei, and 3 Samsung).

ID	Age	Gender	Phone Manufacturer	University Affiliation	Years in Community
P1	23	Woman	iPhone	Undergraduate, Graduate	6
P2	25	Woman	iPhone	Graduate	2
P3	21	Woman	iPhone	Undergraduate	3
P4	21	Man	Huawei	Undergraduate	3
P5	20	Woman	iPhone	Undergraduate	2
P6	31	Man	Samsung	Graduate	1
P7	26	Woman	iPhone	Graduate	3
P8	23	Non-binary	Google	Former Undergraduate	5
P9	23	Woman	iPhone	Graduate	1
P10	26	Man	iPhone	Graduate	2
P11	26	Woman	iPhone	Graduate	1
P12	25	Man	iPhone	Graduate	2
P13	25	Woman	Samsung	Graduate	2
P14	27	Woman	iPhone	Undergraduate, Graduate, Faculty	7
P15	21	Woman	Samsung	Undergraduate Student	3
P16	27	Man	iPhone	Graduate Student	4
P17	44	Woman	Google	Graduate Student	Less than 1

Table 3.1: Participant demographic data

3.2.2 Procedure

Participants read an information letter and signed a consent form before scheduling a time to participate in the study. They were then asked to download the Zappar app to their personal smartphone and to review a set of instructions for the zappar app in advance of the study session. They were also asked to clear a 1m squared well-lit space in which to complete the study. Participants also completed a demographic questionnaire, a questionnaire assessing previous experience with virtual environments, and the Community Connectedness Scale [33].

At the beginning of the remote session, conducted over Microsoft Teams, participants were asked to turn on airplane mode or do not disturb on their phone to ensure there were no disruptions during the study, and began screen recording using their phone's native software. They then were asked to view each of the four visualizations in sequence (1–4).

They used the Zappar app on their phone to scan a 'ZapCode' (similar to a QR code) to open the visualization. They were then instructed to explore the visualization freely, to 'think aloud' as they did so, and to ask questions of the researcher if they had them. Before moving on to the next visualization, they were asked a few short questions about the data to test for comprehension. The visualization session took approximately 15-20 minutes.

After participants completed viewing all four visualizations, they completed the Community Connectedness Scale [33] again, followed by the Reflection Inventory [11], and the Microsoft Desirability Toolkit [10]. They completed a brief semi-structured interview that followed-up on survey metrics, and asked participants what they liked, what they did not like, and what they would change. Interviews typically lasted approximately 30 minutes. Participants were then asked to send their screen recordings to the research team via Microsoft OneDrive, thanked for their time, and provided a $20 CAD honorarium.

3.2.3 Data Collection and Analysis

Our main data collection tools were: (1) the Community Connectedness Scale [33], (2) the Reflection Inventory [11], (3) Microsoft Desirability Toolkit [10] and (4) semi-structured interviews. The Community Connectedness Scale to test has not been validated in the context of testing for pre-/post-study differences for technology. We adapted the scale for this purpose in our study, and reflect on implications of this choice in our Discussion of results (section 5.1). The MS Desirability Toolkit comprises 118 descriptive words that can be selected by participants to help them elucidate their experience when using software prototypes. As an intended use case, we selected a subset of 25 of those words that participants could choose from in describing their experience with our visualizations.

We report descriptive statistics for The Reflection Inventory and summary data for the Microsoft Desireability Toolkit responses. The Community Connectedness data was tested for normality using a shapiro-wilk test. Normality was violated and we therefore used non-parametric Wilcoxon signed-rank tests to investigate differences in pre/post questionnaire responses.

We conducted a deductive, semantic, iterative codebook thematic analysis to analyze our interview data. Interviews were audio and video recorded by Microsoft Teams with auto-transcription enabled. We then manually verified and corrected the automatically generated transcriptions before de-identifying them. The codebook thematic analysis was conducted by the first author in an iterative deductive semantic manner. Our goal was to describe what was said by participants as they relate to our quantitative measures assessing community, reflection and desirability to give context to the findings from our Community

Connectedness Scale, Reflection Inventory, and Desirability Toolkit. Initial sub-themes and codes were developed from interview notes. Next, the initial codebook was imported into NVIVO along with the transcripts for coding and theme generation. From here the iterative coding process continued, with several rounds of coding to describe what occurred.

Chapter 4

Results

Our results have a quantitative aspect including: responses to the reflection inventory, changes to community connectedness, and responses to the MS desirability toolkit. We also have qualitative data from the thematic analysis of interview data. For the thematic analysis we developed three overarching themes based on the semi-structured interviews.

4.1 Quantitative Results

4.1.1 Reflection Inventory

Responses to the Reflection Inventory (Figure 4.1) indicated that participants felt that the visualizations prompted them to reflect on their relationship with their community. The median participant in our study agreed or strongly agreed with every item on the questionnaire: 'The experience gives me ideas on how to overcome challenges' (RI1), 'I learned from exploring the data' (RI2), 'I enjoyed exploring the data' (RI3), 'I reflected on my own experiences with mental health' (RI4), and 'The app would help me discuss mental health and resources with others' (RI5). The median participant strongly agreed with statements that involved internal perceptions of reflection, enjoyment and learning (RI2, RI3, and RI4). Moreover, the median participant agreed with statements that involved external action from the visualization such as getting ideas on how to overcome challenges (RI1) and discussing mental health and resources with others.

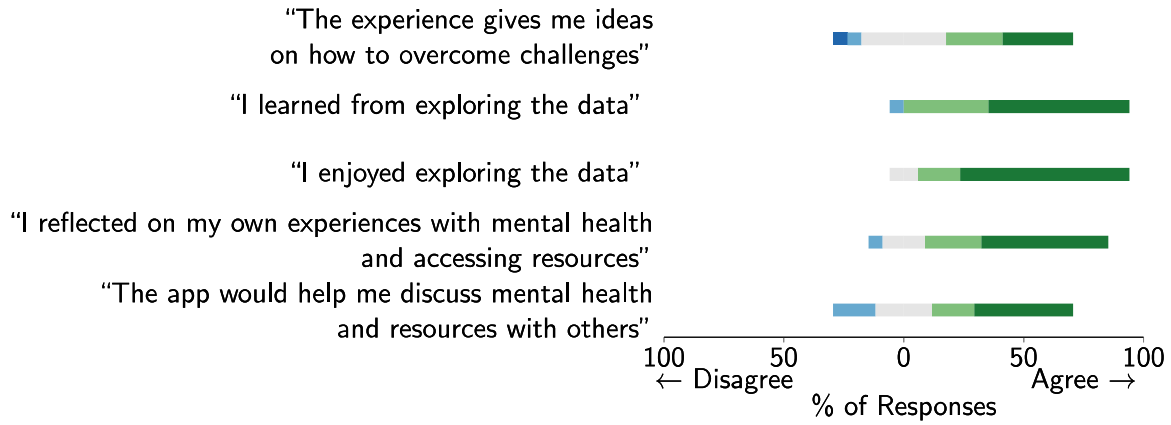


Figure 4.1: Reflection inventory responses

4.1.2 Community Connectedness Questionnaire

We first used the Shapiro-Wilk normality test to check assumptions for a t-test. Responses for each questionnaire item were found to violate the assumption of normality: (CC1: $W = 0.79848, p = .001934$), (CC2: $W = 0.85696, p = .01372$), (CC3: $W = 0.85594, p = .01323$), (CC4: $W = 0.70335, p = .0001262$), (CC5: $W = 0.88688, p = .04117$), (CC6: $W = 0.89158, p = .04921$). Based on these findings, we then used Wilcoxon signed-rank tests to test for differences in each questionnaire item.

We found significant increases in agreement for the statements "It is important for you to be aware of issues others face in your community" (CC5: $V = 10, p = 0.03301$) and "I feel aware of issues that others face in my community" (CC6: $V = 15, p = 0.03082$). We did not find significant changes in agreement for "You feel you are a part of the University community" (CC1: $V = 30, p = 0.8319$), "Participating in the University community is a positive thing for you." (CC2: $V = 26.5, p = 0.6675$), "You feel a bond with the University community." (CC3: $V = 22.5, p = 0.179$), or "You are proud of the University community." (CC4: $V = 34, p = 0.4374$).

4.1.3 Microsoft Desirability Toolkit

We also used Microsoft's Desirability Toolkit [10] to assess user response to our app. Participants could select any number of words from a 25 word list that included both positive and negative words. In total, 103 words were selected by the 17 participants: 82 positive

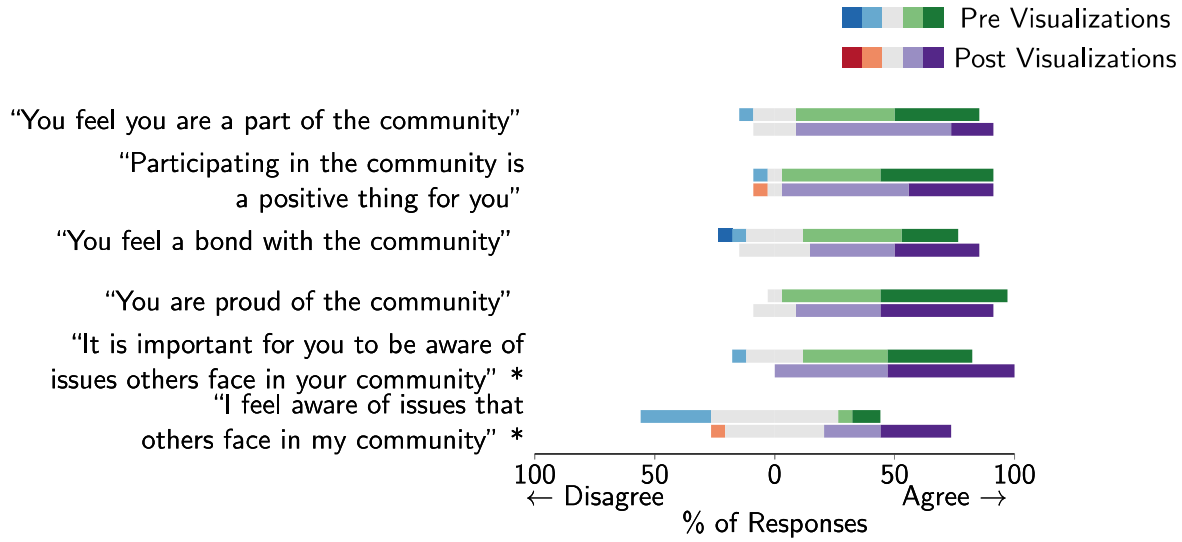


Figure 4.2: Community connectedness responses (* indicates statistical significance)

and 21 negative (Table 4.1). While almost 80% of all words chosen were positive, our exploratory analysis also revealed that 3/17 participants (P4, P6, P8) used 50% or more negative words, and all of them included the word "annoying". While participants were allowed to select as many words as they wanted, the median participant chose 6 words, the smallest number of words picked was 3 and the largest number of words picked was 10.

4.2 Qualitative Results: Thematic Analysis

In this section we present the main themes of our thematic analysis, which are described in Table 3. To illustrate these themes, we draw on quotes from participants' reactions to the visualizations, where the participants were encouraged to "think aloud", as well as a follow up semi-structured interview where they were asked about their survey responses. Please see Appendix A for a more detailed chart of the themes.

Positive Words	Frequency	Negative Words	Frequency
Creative	13	Overwhelming	5
Innovative	12	Confusing	4
Engaging	11	Hard to Use	4
Meaningful	10	Annoying	3
Useful	8	Boring	1
Cutting Edge	7	Irrelevant	1
Easy to use	6	Not Valuable	1
High quality	6	Poor quality	1
Compelling	3	Slow	1
Relevant	3	Too Technical	1
Empowering	2		
Personal	1		

Table 4.1: Desirability toolkit responses

4.2.1 Community

Overall, many participants expressed a sense of connectedness with their peers while exploring the visualizations. For instance, P9 explained "My program's been primarily online, so I do feel connected up to a point, but it's all online and it's all like. [..] I would say I'm a bit more connected and kind of my bubble of what I'm learning for school. But I do think seeing like the data visualized, I did feel more connected here as a student." Participants also expressed that they felt represented by the data, and that it prompted them to consider how they fit with the data. P3 stated, "[There are] 27% graduate [students] [...] when I look at this, it kind of reminds me of myself."

There was also a sense of connectedness to the data itself and with their relation to it. This can be clearly seen in a quote from P10 stating, "In most of the most of the instance, I felt I was, like, connected to the data. And you know, like I could understand like the the relation with the data because I have used a couple of resources. And I also like learned a lot more things today". P15 stated that, "I think most of the time when I was looking through it, half the part of my brain was thinking ohh yeah, like I relate to this."

Some participants felt a connection to the physical space of the community. P7 said, "I especially like the last map part. It almost like felt like I'm in campus and I could easily understand, like, well, what is what? And I could all relate to all the experiences I had, all the resources I used and where I went for and yeah, that, that that last part was really

Theme	Description
Community	How a participant relates to their community, (e.g., feelings of belonging) and their emotional reaction to other people's experiences in the community (e.g., feelings of empathy)
Reflection	The reflection theme had three main conceptual subthemes, (1) reflecting on their experiences in the community, (2) learning about the community, and (3) positive feelings about the visualizations.
Barriers to participation, use, or interpretation	Participants explained how they felt the visualization could be improved, or limitations of mobile AR as a technology. For example: difficulties with navigation, or feeling the app is difficult to use.

Table 4.2: Summary of main themes from thematic analysis

good."

However, connectedness did not always increase and the same information could produce opposing results depending on the participant. For example, P5 stated, "So I actually feel like less [connected to my community]. I feel like I don't know that much about what people are facing or like people aren't. A lot of people won't tell you that they are facing these issues, so I feel less [...] more disconnected." In other words, P5 felt less connected because they had not realized the mental health challenges peers faced. This is in contrast to participants like P7 who said they felt less alone from interacting with the visualizations. "I think even this could be utilized in understanding that I'm not alone, there are other people as well, looking at the data who are suffering in the same way. [...] So I know that, OK, I'm not alone in that battle."

4.2.2 Reflection

Some participants were surprised by the data, and this surprise led to reflection about the university community and their place within it. P10 was surprised by how prevalent academic issues were, "OK, so around 58 percent, 59% of students like feel like academic is like so difficult or very difficult. That's like kind of shocking." and was simultaneously

surprised by how infrequent financial issues were in the community, "Finances, only 29.5% people [...] I feel that number is like, uh low. It's just like 820 students out of 2481, which is like 20% of the students and that I feel like, I mean I felt it would be a bigger number." The participant's reflections in this case put the data into context with their own expectations and experiences.

Another important aspect was an individual's relationship to the community including online status and citizenship. Participants recognized that an individual's background might change the types of mental health issues they deal with. P17 stated, "I mean it depends, right? What kind of stress people are facing. If it's 20 year old person, the mental health issues are completely different if someone in their 50s doing PhD or graduate studies. I mean, I feel like it has to be differentiated if it's like someone who was born in Canada or someone who came as an international student." These sorts of feelings are corroborated by other participants such as P12 who stated, "It's difficult to cope up with the academics and especially the finances as well because I am an international student as well. And I know how expensive [the university] is."

Overall, participants described the immersive visualization experience as novel, memorable, and as allowing them to interact with the data in a unique manner. P5 said, "So like it's not something I would like forget because usually like handouts and stuff. Like I always forget after because it's like not a very... this is a unique experience. I don't think I could forget this data." P9 felt that the mobile AR platform made the data more tangible, saying that "seeing it right there, right in front of you, its is as if you could almost like touch the data."

Reflecting on how the visualizations could be useful to the community

Our work also uncovered what the community felt the visualizations would be useful for including: referring other students to resources, destigmatizing mental health education, and encouraging students to engage with the mental health information.

Some participants like P1 and P14 thought that these visualizations could be useful for referring students to resources. P4 said, "I like thinking about if I had a student in a course I'm TAing and asking for resources I would look at that to see like, oh, these are like, you know, some mental health resources. These are some, I can't remember all the breakdowns. Now when was academic resources. Yeah, I think that would be great." P14 also echoed this sentiment saying, "Like as an old person like a senior person who's been at Waterloo for a while and like an orientation leader I would recommend this to freshmen."

There were also participants who felt that the visualizations made them feel less alone in mental health struggles and that it could destigmatize seeking mental health help. P15 said, "I think it could be valuable to the community and seeing that people aren't alone and that there are a lot of people who are feeling the same way and it doesn't have to be a topic that people avoid having conversations about like it usually is with mental health."

There is also a theme of novelty and that some participants said that the immersive visualizations could be more impactful than more traditional forms of health communication. P10 said, "Its something new. Maybe people would be more motivated in viewing this. So I feel, people would get more easily motivated and you know, like more I would say inspired or to view these resources." P2 had a similar experience and felt that this mode of information visualization made the data feel more tangible, "It helps make it feel more than just a statistic. It helps you actually visualize that these numbers are more than just, you know, numbers. They are reflective of counted individuals and cases."

Barriers to Participation, Use, or Interpretation

Participants described some of the difficulties that they experienced, particularly with respect to navigation. Although participants were instructed to physically move around the visualization, some did not. One participant described how they forgot that was an option. Another, P14, explained that exploring the visualization would be difficult in their environment: "I can't see half the other half of the graphic because it's against the wall, if that makes sense. Like it's, yeah, if I could spin, I don't know if you can do that on blender, but if you can." To resolve these issues, some participants reported that additional navigation features would be helpful. For instance, some expressed a desire to navigate the visualizations using interaction metaphors from desktop or touch computing, like pinch-to-zoom. Others suggested offering more features, like P16 who said, "I know where some of these resources are but [...] maybe like I could click on them on the flag and then you could open like a Google Maps or something."

Previous experience with immersive environments and technology appeared to play a role in defining barriers. Some people had experience with headset AR/VR and felt that mobile AR was outdated. For example, P12 suggested they would have preferred headset VR. P8 was more direct, saying "OK, alright, I know I'm much more used to headset VR than looking through a phones kind of something I haven't really done since 2016." Others with less experience expressed the opposite, feeling that mobile AR was a barrier to broader adoption. P17 said, "I feel like you're very innovative and you know future forward. I don't think like in a big scale if it got released into the public it would be adopted easily because I know people just started to get used to mobile devices [...] Like in university community,

you know it's it should be fine. I don't feel that it's gonna be challenging. But for public health in general [...] it will be very skewed just for early adopters and people who are very comfortable with technology."

Chapter 5

Discussion

Here we will interpret our results and discuss their potential for fostering community connectedness. We then dive deeper into potential implications of our work as relating to our field tests. These include role of navigation space and personal identity which we are able to discuss as our field tests used personal spaces and smartphones. Additionally, we discuss the public health implications of our work including their potential for increasing help-seeking behaviour.

5.1 Immersive Visualization can Increase Community Connectedness

Overall, our immersive visualizations fostered feelings of connectedness and reflection — particularly in respect to awareness of issues facing the university community. Responses to the reflection inventory questionnaire indicate that participants enjoyed the visualizations, and that they learned about their community and reflected on their own experiences and mental health. These responses corroborate changes in feelings of awareness about the university community (CC6, $p = .03082$), and the importance of that awareness (CC5, $p = .03301$). Positive responses to the reflection inventory and the MS desirability toolkit further support these interpretations. These findings point to the potential efficacy of immersive visualization as a medium to increase awareness of one's community.

We did not observe differences in the other items of the Community Connectedness Scale (CC1-CC4). With regard to these findings, we note two important considerations for this data. First, our visualizations explored some very serious issues like mental health,

chronic stressors, and other systemic issues at our institution. Understandably, this focus may have deterred participants from, for example, 'feeling proud' of their institution (CC4) or feeling that participating in the community is a 'positive thing' (CC2). Second, despite participants working remotely throughout the pandemic, Community Connectedness Scale responses were quite positive *before* the study started, and so there was limited opportunity to increase many of them. It's possible that, had our focus been on more positive elements of the community identity like its academic successes that our findings may have been different. Future studies are required to investigate other aspects of community connectedness, if these feelings are long term and to investigate alternate community issues.

5.2 Challenges for Designing Mobile Immersive Vis

Finally, our research through design process and field study provided opportunities to investigate the *in situ* use of immersive visualization, in participants' homes and with their personal smartphones, and to reflect on both practical issues and 'grand challenges' [30, 6] related to this use. To examine how these issues impacted participants' feelings of community connectedness, we focus here on discussing three challenges identified during our study: navigation, placement in the environment, and identity.

5.2.1 Navigating 3D space and integration with the real world

Our visualizations *required* participants to physically navigate — walk around — the data. This affordance of AR is often considered to be beneficial, to remove barriers between individuals and the data, and to create more engaging, embodied tools that support understanding [61]. Indeed, many of our participants recognized these benefits, reporting that they felt like they were "connected to the data" (P10), and described the visualizations as 'empowering', 'meaningful', and 'engaging'.

However, other participants stated a need for more traditional methods of navigation like pinch-to-zoom. Some reported that they did not expect the need to walk around the visualization, or described the visualizations as 'confusing', 'overwhelming', or 'hard to use'. Other participants were in a space that did not allow physical navigation because they were too small or contained obstacles like furniture. These challenges underscore the need for further research into the grand challenge of navigation within immersive visualizations (e.g., [30]).

5.2.2 Reflecting on Future Design Steps

In hindsight, there are several design decisions that were made that could have been improved upon. These range from simple changes such as higher contrast colour-blind friendly colours and increasing text size, to more complex changes like phone space limitations, exploring different interaction paradigms, as well as how future real-world deployments might look.

There are design tensions between creating detailed high fidelity visualizations and the capabilities of the various phones that were available to our participants. For our purposes we prioritized small quickly downloadable visualizations, in order to be accessible, work on many mobile phones, and be downloadable on demand. This choice limited us to low-poly visualizations and to avoid implementing more computationally or size intensive immersive features such as audio or animations. We could have addressed these issues by having participants download all visualizations at once via an app, or deploying via a more complex visualizations via headset AR.

Looking back, I would have also linked the visualizations more conceptually, and emphasized the storytelling aspect more. Future research into immersive mobile AR visualizations could also investigate the potential of AR support on social media apps such as Snapchat, Instagram and TikTok. While a user may not think of it as AR, many ubiquitous filters include AR elements on the user's face or in the user's environment. Perhaps uploading visualizations to already used social media apps with AR support would allow visualization designers to meet users where they are and deploy their work more widely.

5.2.3 Limitations and Affordances of Space

Our results show how an individual's environment can limit their ability to experience immersive visualizations. Our field test asked participants to prepare a well-lit 1 metre squared space in which to use their personal smartphone in their home. However, in practice not all participants were able to create optimal spaces. Some worked in smaller spaces than others, some had cluttered workspaces, some were poorly lit, etc. These different living spaces in-turn influenced how fully they could engage with the visualizations.

These issues provide insight into the challenges faced by "real world deployments" of immersive visualizations, and the need for researchers and designers to anticipate and account for these differences. In fact, while we observed a wide range in participants' smartphones technical capabilities, the variety in their living spaces was a far more significant consideration for how they experienced and engaged with the data. We therefore raise the

question: what does *responsive design* require for immersive visualization? That is, how can immersive visualizations anticipate and adapt to a viewer's environment to enable them to engage with the material? If designers anticipate a smaller, more crowded space, the visualization should take up less area in the viewport, or perhaps give opportunities to choose a simpler interaction paradigm.

5.3 Our identity influences how we experience immersive visualizations

Personal identity and self-reflection were also major themes of our investigation. Many participants used our visualizations to reflect on how their own experiences were different from that of their peers. Although we knew our university community was diverse, and expected to learn about a variety of identities and lived experiences, we did not anticipate how difficult these factors would be to capture in our experiment. For instance, we could have collected higher granularity of demographic data with respect to socio-economic and mental health information, as well as more in-depth descriptions of their personal relationships to the university and its community.

These findings highlight the need to better account for identity and diversity in immersive visualization research. They also build and expand upon recent calls from within the human-computer interaction research community to explore how factors like gender [57], culture [54], and identity [42] influence our experiences with technology. Our research provides perspective on how these parts of identity deeply impact how people experience immersive visualizations, and the need to better understand how it might shape the use of such visualizations in complex contexts like public health.

5.4 Potential for increasing help-seeking behaviour

Our work asks the question - How might immersive visualizations be useful as an interactive health technology? We set out investigate how and if a university community could benefit from immersive visualizations. Overall, we successfully increased participant's perceptions of community connectedness related to awareness and importance of issues, had 80% positive words in the desirability toolkit and the median participant strongly agreed or agreed with all metrics of the reflection inventory.

These positive results indicate that immersive visualizations could potentially be used for student populations to increase help-seeking for mental health concerns. Notably, we have shown significant increases in metrics related to awareness and community: "It is important for you to be aware of issues others face in your community" (CC5) and "I feel aware of issues that others face in my community" (CC6). The reflection inventory also shows potential with participants agreeing that: "The experience gives me ideas on how to overcome challenges" (RI1) and "The app would help me discuss mental health and resources with others" (RI5). Although we have not directly investigated how our visualizations may impact help-seeking behaviour, these results indicate that there is potential in this space. Future work should investigate directly if immersive visualizations could increase help-seeking for mental health.

Some participants also felt that the novelty and interactive factor of the visualizations might motivate people to engage with the information presented. For example, P10 stated, "Its something new. Maybe people would be more motivated in viewing this. So I feel, people would get more easily motivated and you know, like more I would say inspired or to view these resources." While most public health communications errs on the side of being accessible, there is the potential that having more novel and interactive IHTs could result increased adoption and health-seeking behaviours.

In the final chapter we discuss implications, limitations and future work.

Chapter 6

Conclusion

In this section we will reflect upon our work as it fits into the field of immersive visualization and interactive health technologies.

6.1 Implications for HCI

Although immersive visualization research has largely focused on technical contributions [30], we have shown its potential as a public health tool. Our research through design process demonstrated how immersive, mobile AR visualizations might be used to increase feelings of community. Our field study has used human-computer interaction methods to demonstrate the potential for attitude and behaviour change [51], and we expect that future work can now extend and build on these findings to demonstrate their utility to the health research and practice communities, and to establish immersive visualization as a useful tool for education and health promotion. That is, immersive public health visualizations can challenge assumptions about how data is viewed and who is viewing it, removing the barriers between people and data as envisioned by Marriott et al. [61].

Our work also contributes novel methods for designing and evaluating immersive visualizations that seek to promote community connectedness. To our knowledge, despite recent interest in understanding how to design more humane visualizations (e.g., [15, 67]), community connectedness has yet to be explored in the human-computer interaction or visualization research communities. Our study shows how the Community Connectedness Scale [33] might be used to measure and understand changes related to the use of immersive visualizations.

Importantly, the needs of the human-computer interaction community differ from those of other fields like psychology (e.g., [23]), where useful measures must not only show differences in connectedness but should also provide researchers and practitioners with insight into *how* technology might elicit such changes. So our results show the utility of these measures in HCI research, and demonstrate methods for their use in a practical setting, but also the need for more powerful design tools. We also expect that these tools could be useful for human-computer interaction researchers investigating community connectedness in novel contexts, like social networks (e.g., [34, 4]), games (e.g., [21, 70]), or 'the metaverse' (e.g., [90]).

6.2 Implications for Public Health

6.2.1 Reflecting on our visualizations as an interactive health technology

Our research through design approach addressed some of the concerns that exist for IHT, including issues with measuring performance of the technology. Our mixed methods approach included iterative cycles of development, allowing for a product that performed well on our numerous assessment metrics. While Inal et al. [47] found that most IHT papers only collected data on one performance metric, we took an integrated approach and collected data on usability (MS Desirability Toolkit), reflection (Modified Reflection Inventory), community (Modified Community Connectedness) and performed a thematic analysis. Our mix of qualitative and quantitative data gathering techniques allowed us to centre participant expereince.

Next, we will discuss the issue of adoption of IHTs and how a theoretical distribution of our visualizations may look outside of a research environment. Currently, a large limitation is that the visualizations have to be experienced through downloading an app. However, if we could implement a version that can be viewed through a web-app and allow access through scanning a QR code it would allow for easy access to the information for most students. Several participants in the study mentioned that they could see these visualizations being useful in an environment like frosh week or club fair. If we implemented our AR visualizations in this manner we could potentially measure different attitudes towards technology and mental health in different year cohorts.

Immersive visualizations also have a wider potential for public health outside of University context. VR and AR have already been used for education [18] and as a health

intervention [20]. Potentially hospitals or other health organizations could use these applications to educate, gather information and feedback on experiences.

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6.2.2 Limitations

We engaged in a research through design process to explore the rich and complex design space of improving community connectedness through immersive visualization. This approach was particularly helpful as we had to take into account many factors such as health, technology, and social dimensions such as if data was appropriate to visualize. Our goal was to create *extensible* knowledge [45] that can serve as a proposal for how these visualizations might evolve rather than a prediction of what is likely to be effective in practice [104]. Despite these strengths, our research also has several limitations that are worth discussing:

One limitation of our approach is that we did not include a 'baseline' or 'control' condition in our field study, and so while we found an increase in community connectedness after use of the immersive visualization we cannot quantify the strength of its effect. We also cannot know which of our 4 visualizations were most effective, or if specific combinations of them would be more effective, or if any of the visualizations may have independently *decreased* community connectedness. Indeed, our study also focused on measuring short-term effects, and additional studies are required to assess the potential for long-term changes in attitude or behaviours. Our field tests are consistent with evaluations for health behaviour change in HCI (e.g., [51]) and research through design (e.g., [105, 104]) processes, but points to a need for future work to more closely examine the trends we have identified.

Another limitation is our choice to design mental health education for the university population. Although this group offers rich data and a technologically literate population, we cannot expect that our results would hold outside of a western, young, and highly educated population [54]. Indeed, our findings underscore the importance of understanding contextual factors like an individual's identity, role within the community, health and finances. We view these limitations as calls-to-action from the human-computer interaction community to better account for diversity in our research processes (e.g., [57]).

Our work shares many of the limitations of other interactive health technologies. Notably, we did not distribute our visualizations to the community and assess if they would be adopted. It would be a good next step to make our visualizations accessible to the community and to see if students would actually use our visualizations outside of the study context. This is a large ongoing problem within the research area of IHTs and true

widespread dissemination is not typically assessed. This is an interesting opportunity for future work and we speculated on how a potential adoption might look in the section above.

Finally, we used the Community Connectedness Scale [33] to measure differences in community connectedness for members of a university community before and after use of our visualizations. Both the university community and use for pre-/post-intervention testing are novel, untested uses of the scale, and so our results need to be interpreted with caution. Validated scales for community connectedness are currently an active area of psychology research (e.g., [23, 31, 74]), but have yet to be developed for research communities interested in technology design. Additionally, there are many different understanding of how communities interact in both the health and HCI research areas. We adapted the Community Connectedness Scale because it is a validated scale and provides some insight into how and why individuals might feel connected to their community. However, we expect that as interest in designing for community connectedness increases, that more appropriate and descriptive tools may be required by the human-computer interaction community.

6.3 Summary

Our work demonstrates how mobile, immersive visualization can be used to increase an individual's sense of community connectedness. Our field study showed that immersive visualizations can elicit changes in community connectedness, and that participants used the visualizations to reflect on their role in the community, their similarities and differences with others, and their awareness of those similarities and differences. These findings motivate the need for additional research by the human-computer interaction community on how immersive visualization might be used to make our communities more connected.

Again, our four contributions were: (1) our research through design approach which gave rise to 4 visualizations about student mental health and resources, (2) the introduction of the public health concept of community connectedness to the field of human-computer interaction, (3) a proof of concept that immersive visualizations can increase community connectedness, (4) a discussion issues in mobile AR as learned from our field tests including: the role of identity, navigation and space as revealed through our field tests using participant's phones and home environment.

In making these contributions we have also shown how immersive visualization might serve as an important public health tool. We have adapted methods from the psychology and public health literature to show changes in community connectedness after viewing visualizations. Our work shows that immersive mobile AR visualizations have great potential for creating awareness of issues and fostering a sense of community. Of course more

work needs to be done in this space, however we demonstrate promising first steps for this area of research.

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APPENDICES

Appendix A

Thematic Analysis

Below is a more detailed figure of the thematic analysis codes and themes.

Theme	Sub-theme
Community	
	Awareness of issues and importance of issues
	Belonging in the community
	Empathy for others in the community or imagined experiences of others
	Past experiences in the community
	Feeling disconnected from community
Reflection	
	Feeling the data represents what you expected
	Learning
	Personal experiences with mental or physical health
	Positive feelings on app or design
	Applications or usefulness of the app and the experience
Hindrances to participation, use or interpretation	
	Being initially confused but finding it easy to use later
	Blaming themselves for finding the app difficult
	Bugs or missing information
	Desiring non-implemented features
	Features perceived as hard to use
	Wanting alternate mode of information visualization
	Not paying attention to content due to interface being too distracting
	Perceiving app as inefficient for information retrieval
	User error

Table A.1: Thematic analysis main themes and sub-themes

Appendix B

Survey Tools

Below are the complete survey tools used. Please find the citations for each here Community Connectedness Scale [33], Reflection Inventory[11], and the Microsoft Desirability Toolkit [10]

B.1 Adapted Community Connectedness

1. You feel you are a part of the Waterloo community.
2. Participating in the Waterloo community is a positive thing for you.
3. You feel a bond with the Waterloo community.
4. You are proud of the Waterloo community.
5. It is important for you to be aware of issues others face in your community
6. I feel aware of issues that others face in my community

B.2 Adapted Reflection Inventory

1. The experience gives me ideas on how to overcome challenges
2. I learned from exploring the data

3. I enjoyed exploring the data
4. I reflected on my own experiences with mental health
5. The app would help me discuss mental health and resources with others

B.3 Demographics Questions

1. What is your Participant ID
2. Please select your gender (Man, Woman, Non-binary, Prefer not to disclose, Prefer to self-describe)
3. Please select your sex (Male, Female, Prefer not to disclose, Prefer to self-describe)
4. Please enter your age
5. Please select the highest level of education you have completed (12th grade or less, Graduated high school or less, Some college, no degree, Associate degree, Bachelor's degree, Post-graduate degree, Prefer not to disclose)
6. Are you or have you been a college or a university student?
7. What is your relation to the University of Waterloo? (Undergraduate Student, Graduate Student, Alum, Faculty, Other)
8. How many years would you consider yourself to be part of the University of Waterloo Community?
9. What is your occupation?
10. Do you have experience with Headset AR/Headset VR?
11. If yes, please describe your experience
12. Do you have experience with mobile AR?
13. If yes, please describe your experience
14. What smartphone do you have?

B.4 Desirability Toolkit

Below are all 25 words from the desirability toolkit for participants to choose from. "Select all words that you think apply to your AR experience"

- Annoying
- Boring
- Compelling
- Confusing
- Creative
- Cutting edge
- Easy to use
- Empowering
- Engaging
- Hard to Use
- High quality
- Impersonal
- Innovative
- Irrelevant
- Meaningful
- Not Valuable
- Overwhelming
- Patronizing
- Personal

- Poor quality
- Relevant
- Slow
- Stressful
- Too Technical
- Useful

Appendix C

Ethics Application

PROTOCOLS

UNIVERSITY OF WATERLOO

#43374 - Fostering Community Connectedness Through Interactive Augmented Reality Information Visualization

Protocol Information

Review Type	Status	Approval Date	Renewal Date
Expedited	**Approved**	**Oct 21, 2022**	**Nov 15, 2023**

Expiration Date	Initial Approval Date	Initial Review Type
Dec 07, 2023	**Dec 06, 2021**	**Expedited**

Feedback

Approval Comment

Renewal approved. Study may continue for another 12 months- JE

Protocol Renewal Form

Renewal form

What kind of application are you renewing?
Standard Application/Imported Record

What is the status of the study?
Participants are being recruited or participation is ongoing

Approximately how many participants are left to recruit?
We are awaiting reviews for a paper on this study and anticipate more participants may be needed. Potentially 10-20 more participants may be required.

In the past 12 months, have any participants withdrawn from the study?
No

In the past 12 months, have any of the following issues occurred, but have not been reported to Research Ethics?
No unreported events/changes

Does your project involve research with Indigenous people?
No

Does the study involve the delegation of a controlled act? (e.g., venipuncture, ultrasound, x-ray, etc.)
No

Renewal Confirmation

By submitting this renewal application I am requesting to extend the study another 12 months

The following list outlines project changes that typically need to receive ethics clearance through an amendment to the project prior to implementing the change.

General Information

Only the Principal Investigator/Faculty Supervisor can submit the application. This acts as a signature indicating approval of the application.

Principal Investigator / Faculty Supervisor

James Wallace

Department

School of Public Health Sciences

Study title

Fostering Community Connectedness Through Interactive Augmented Reality Information Visualization

General Questionnaire

Indicate the type of application you would like to complete

Standard application *

*** The Standard application is for faculty level research and thesis level research.**

**** The course project application is for (non-thesis) course based research and can be completed by students or the course instructor**

Please confirm:

I understand that the type of applications listed above determine the form I am about to complete. If I have chosen the incorrect form I acknowledge that I may need to complete a new application.

People

University of Waterloo research team

Person

James Wallace

Waterloo Department

School of Public Health Sciences

Email Address

jrwallac@uwaterloo.ca

Phone

Researcher Role

Principal Investigator

Permissions

Full Access

Has this person completed the CORE (TCPS2) tutorial?

Yes

Date of completion on TCPS2 certificate (Required)

January 21, 2013

Upload a copy of the TCPS2 certificate (Highly recommended, optional at this time)

TCPS2_CORE_CERTIFICATE.PDF

As per the Waterloo policy on mandatory research ethics training, if you completed the TCPS2 tutorial more than 5 years ago, you may be asked to update your training within the next 6 months. You will be notified by email if this is the case.

Person

Rachel Woo

Waterloo Department

School of Public Health Sciences

Email Address

r3woo@uwaterloo.ca

Phone

Researcher Role

Student investigator

Permissions

Full Access

Has this person completed the CORE (TCPS2) tutorial?

Yes

Date of completion on TCPS2 certificate (Required)

May 8, 2021

Upload a copy of the TCPS2 certificate (Highly recommended, optional at this time)

TCPS2_CORE_CERTIFICATE.PDF

As per the Waterloo policy on mandatory research ethics training, if you completed the TCPS2 tutorial more than 5 years ago, you may be asked to update your training within the next 6 months. You will be notified by email if this is the case.

Person

Daniel Harley

Waterloo Department

Stratford School of Interaction Design and Business

Email Address

daniel.harley@uwaterloo.ca

Phone

Researcher Role

Faculty supervisor

Permissions

Full Access

Has this person completed the CORE (TCPS2) tutorial?

Yes

Date of completion on TCPS2 certificate (Required)

May 6, 2021

Upload a copy of the TCPS2 certificate (Highly recommended, optional at this time)

HARLEY_CORECERTIFICATE-MERGED.PDF

Do you have any investigators external to the University of Waterloo

No

General details

Is this new study related to any previous application?

No

What is the estimated start date and end date for the study?

Start Date

August 1, 2021

End Date

July 31, 2022

Does this research require approval from a UWaterloo departmental committee?

Not a department requirement

What is the level of the research to be conducted? Choose one.

Master's thesis

Will this study involve Wilfrid Laurier University, Western University, Conestoga College or Local hospitals covered by the Tri-Hospital Research Ethics Board (Cambridge Memorial Hospital, Grand River Hospital and St. Mary's General Hospital)?

No

Has a version of this study been disapproved or rejected by any Research Ethics Board/Committee?

No

Special Instructions RE: Research During COVID-19 Pandemic
Are you proposing in this application a study that involves in-person (face-to-face) research activities either on-campus or off-campus?

No

Study description

State your research question(s)

Information visualization is an essential field in order to discover how to best communicate information. However, information visualization is not well explored for the domains of location based data, augmented reality (AR) as well as community data. Therefore, this study will visualize data relevant to the University of Waterloo community using AR to investigate the following questions. 1. Is location related AR visualization an effective and useful way to display information? 2. Can data visualization make an individual feel more connected to their community? 3. Does the amount of time spent on a visualization affect feelings of community connectedness?

Provide a clear, detailed description of the purpose, hypothesis, aim, and objectives of this study

The purpose of this study is to assess the viability and usefulness to the community of augmented reality visualizations. While some work has been done on how different interaction techniques can result in bonding with data, research hasn't investigated how visualizing data related to a community affects feelings of belonging within the community. To explore this we will design an interactive AR application based on information about and related to the University of Waterloo. This visualization will potentially explore data related to the University of Waterloo such as demographics and mental health. Participants will screen records as they experience the visualization and be observed through a online meeting. The participants will participate in the visualizations and answer questions to ensure the participant is understanding the information. Afterwards, participants will fill out surveys related to demographic information, a survey/semi-structured interview on community connected adapted from Connectedness to the LGBT Community Survey. Participants will also assess application usability from the Desirability Toolkit and answer general questions on if the tool was effective, . The main goal is to assess the viability of this mode of information visualization and its potential benefit to the broader community. We hypothesize that users that participate in the visualization may feel more connected and informed of

their community. This study will contribute to the field of data driven narratives and assess how AR can be used to educate and inform a community.

Provide background information, a rationale, and justification for conducting this study. Describe why the research is being done and what research has already been done in this area. Be sure to explain why this research is important.

Increasingly, people are becoming more and more immersed in the virtual world. Virtual environments are rapidly becoming a pervasive high fidelity means of interaction. The COVID19 pandemic has brought this fact into stark relief. Already there is increased adoption of online technologies and all aspects of our lives have become entangled in the question of how to create collaborative and efficient spaces for people to live their lives. Although immersive technologies are not yet commonplace, it will become normal for people to interact and learn through augmented reality (AR) which merges 3D visualizations with the real world. As 5G and lidar mobile devices emerge onto the market, visualizations will become more common and high fidelity. Even now AR is ripe for exploration as in 2017, 92% of Americans aged 18-29 had a smartphone. One largely unexplored aspect of AR is community driven information visualization. While currently, ordinary people are not creating AR environments, eventually tools will be made to lower the barrier of entry enough that ordinary people will be creating and exchanging location based AR. This boom will open up the possibility for a community created and driven narrative. Our work will explore how AR location based visualizations about a community can make a people feel more connected to their virtual and physical environment. While much work has been done on location based AR in the education, construction, and medicine there is a dearth of research looking into how information visualization and AR interact to foster community. Participants will consent to be involved in the study. Then, they will be asked to book a time to participate, download the app and fill out demographic and initial questions. During the online study participants will experience visualizations about the Waterloo community. Afterwards, participants will fill out surveys on community connectedness, usability and questions if the tool waseffective. Afterwards, there will be a semi-structured semi-structured interview. The main goal is to assess the viability of this mode of information visualization and its potential benefit

to the broader community. We hypothesize that users that participate in the visualization may feel more connected and informed of their community. This study will contribute to the field of data driven narratives and assess how location based AR can be used to educate and inform a community. Through our research we will validate AR information visualization techniques and explore belonging in a physical and virtual environments. Our research additionally contributes by adapting existing community connectedness paradigms to the field of human computer interaction.

In a maximum of 250 words, provide a non-scientific lay language description that summarizes the project outlining the purpose, anticipated benefits, and basic procedures. Write this summary as if it would be read by members of the general public who are not familiar with academic terms or acronyms. Use language suitable for a media release.

Purpose: Augmented reality (AR), or projecting 3D visualizations into the real world on smartphones is becoming more common. While currently, lay people are not creating augmented reality environments for themselves, eventually tools will be made to lower the barrier of entry. When this happens, we think location based AR will become more common and people that often are at a particular location will make AR associated with the location and their own identity. The community based AR will provide a new paradigm for community collective identity and information dissemination. Basic Procedures: For this study we will be looking into how to show graphs and charts about a community and how it makes people feel a part of the community. We think that interacting with information about your community could increase feelings of belonging to your community, awareness of its issues and collective identity. We will specifically learn about how universities can show information to promote information spread and community connectedness. To test if these methods work we will have participants experience our visualizations, then have them fill out surveys on ease of use, and community connectedness and conduct interviews. Benefits: Broadly, our research will contribute to AR information visualization and increase our knowledge of how to use data to tell a story. Academically, our research additionally adapts existing community connectedness surveys from the field of psychology and health to the field of human computer interaction.

What is the study design?

I will be conducting a mixed methods study including qualitative and quantitative metrics. These metrics include the Desirability Toolkit (users choose words that represent their user experience), screen recordings of tool usage to determine the length of time spent, a semi-structured interview as well as likert scale questions on community connectedness and reflection.

Is this a pilot study?

No

Sample Size

What is the expected sample size? Outline the number of participants anticipated to take part in the study.

30

Was a formal sample size calculation completed?

No

Provide a rationale for the number of participants specified

This number is fairly standard for the field of human computer interaction.

Study sites

Where is this study taking place?

University of Waterloo

Are there any permissions required to conduct this study on campus?

Funding

Is the study funded/will it be funded?

Yes

Funding
List all funding sources that are new or ongoing

Funding status

Ongoing funding

Funding source is

Tri-agency / Canadian Government sponsor

Canadian Government agency

NSERC - Natural Sciences and Engineering Research Council of Canada

Program name if applicable

Discovery

Work-order or award number, if known

50503-10006

What is the expected period of funding

Funding from

August 1, 2021

Funding to

July 31, 2022

Conflict of interest

the research team in undertaking the proposed research?
No

Benefits

Are there direct benefits of the proposed research to the study participants?
No

What are the scientific and/or scholarly benefits of the proposed research?

Our research will benefit the scientific community as we will assess the viability of this AR-location based information visualization in the context of community. This approach is novel and we adapt existing community connectedness paradigms to the field of human computer interaction. In doing so, we will validate a novel survey technique. We will also contribute to the field of data driven narratives and assess how location based AR can be used to educate and inform a community. Our research broadly assesses how participating in a virtual physical community hybrid will affect feelings of belonging, which is novel in the field.

Participants

Participant general categories

University of Waterloo undergraduate and/or graduate students
University of Waterloo staff and/or faculty
Adults (age 18-64 years)

Are you conducting research in classes with students as your participants to evaluate a teaching method or object?
No

Describe the sample in detail and list any specific inclusion/exclusion criteria for the study

Inclusion Criteria: Consenting adults in Waterloo region with a compatible smartphone (has a camera, current operating system, compatible browser)

Exclusion Criteria: Not fluent in English, not a member of the University of Waterloo Community

If you are excluding people on certain characteristics provide a justification for the exclusion.

Those not fluent in English are excluded because of the use of certain survey tools. Specifically, the Desirability Toolkit requires participants to select from 118 English words to describe their product experience.

Will a screening process be used to determine eligibility in the study based on the inclusion and/or exclusion criteria identified above?

No

Recruitment

Identify from where/what sources potential participants will be recruited.

Database or Participant Pool
Through email/internet (e.g., social media networks)

Indicate the Database or Participant Pool that will be used in the study.

Potentially e Waterloo HCI SONA system (https://waterloohci.sona-systems.com)

Indicate what email listing, internet site or network you intend to recruit from

We will use university department and institution mailing lists such as the games institute mailing list. We may also email/message potential friends or acquaintances and ask if they can forward the approved email to those who may be interested.

What recruitment materials will be used?

Email script
Social media

Describe how social media will be used

We will post the study detail to relevant social medias such as Facebook and Slack. We will only every post in research relevant groups, use of lab social media or get permission from the administrators of the groups. We will use our social media recruitment letter and poster for these purposes. Relevant groups include but are not limited to Facebook, Facebook messenger chats, and uWaterloo Slack channels.

Upload your recruitment materials

Upload your recruitment materials

RECRUITMENTEMAILREVISED_REVISION2.DOCX

Study group

Upload your recruitment materials

RECRUITMENTSOCIALMEDIA_REVISION2.DOCX

Study group

Upload your recruitment materials

RECRUITMENT_POSTER_3RDEDIT.JPG

Study group

Recruitment Poster

Will potential participants be recruited through pre-existing relationships with members of the research team (e.g., employees, students, or patients of research team, acquaintances, own children or family members, colleagues, etc.)?

Yes

Outline the relationship between the researchers and potential participants (e.g., professor-student, colleagues)

Participants could include but are not exclusive to friends, acquaintances,

colleagues. Anyone who meets the eligibility criteria and has seen the recruitment materials are considered.

Could this relationship compromise the potential participant's freedom to decline participation?

No

Explain

There are no consequences to not participating and everyone has the ability to accept or decline the invitation to participate.

Methods and procedures

Which of the following will be conducted for this study?

Surveys/questionnaires
One-on-one interviews
Observation
Other

Describe the other procedure

Screen-recordings from participants' phones from when the go through the visualizations.

How will the survey(s) or questionnaire(s) be administered?

Online or web

Provide the URL of the survey, if available

In study materials.

How will the one-on-one interviews be conducted?

Online – Video Chat

Will quotations be used in the write-up of the study

Yes

What type of quotations will be used?

Anonymous

What type of observations are planned?

Participant observation (where the researcher engages in, and observes, the action; participant knows they are being observed)

Will the people being observed have an expectation of privacy?

No

Explain why there will not be an expectation of privacy

Participants will be in a recorded online meeting. They will also be told that they will be observed and recorded beforehand.

For each of the procedures indicated above, provide a detailed, sequential description of how they will be used in the study.

Participants will be asked to read the consent form which will explicitly outline the following: what materials we will collect, privacy, if they have a compatible device, as well as study procedure. Participants will complete the consent form and information letter and then proceed to being able to book a time to participate and fill out demographic information. Participants will also be asked to pre-download the app needed to use the visualization. Instructions will be given on how to add and remove the app. Participants will be asked to appear in the online meeting the pre-booked time. A reminder email will be sent a few days in advance to remind participants and will contain the information letter again. Participants will be asked to fill out an initial demographics and connectedness questionnaire before participation. Visualizations Section: Participants will be asked to turn on airplane mode or do not disturb to ensure privacy. The screen recording will be done using their phones native software. Participants will be provided with the visualization cards and how to use

zappar instructions, the pdf will be viewed on a computer. Then, using the Zappar app on their mobile device they will scan the ZapCode (similar to a qr code) to access the visualization. In the visualization (on their smartphone) they will have the opportunity to answer questions in GoogleForms about comprehension and offer additional comments. For the final visualization the accompanying website will be access through their computer. Video demonstrating this workflow was emailed to vbuote@uwaterloo.ca. The screen recording of viewing resource websites is not relevant because participants would open the website on their computer and not their phone. They will then go through our visualization as well as participate in some by going through specific actions such as answering questions to ensure comprehension. The goal of the questions and example questions have been uploaded. The answers to the questions will be used in the study but will only be shown within the research team. Participants will be self-directed but able to ask questions to the researcher if needed. Participants will be asked to "think aloud." Participants will screen record their experiences using the visualizations, researchers may also note down behaviour and reaction to the visualization such as perceived confusion. The expected completion time is approximately 30 minutes for this section. Survey and Interview: The participants will then fill out the community connectedness survey, asked usability questions and complete the desirability toolkit. Participants will also be asked to send the screen recording to the research team via email. Participants will then do a semi-structured interview. This interview will be recorded. The interview will follow up on survey metrics as well as ask broadly what participants liked, did not like and what they would change. Zappar Privacy and Screen recording concerns: The Zappar app privacy policy can be found outlined here: https://www.zappar.com/privacy/ . The most relevant part of the policy can be found here: “When you use the Zappar App, the ZapBox App or our WebAR, our servers will automatically access or collect information from your device (e.g. smartphone), including the following: an Installation ID (see below); the IP Address linked to the device: we will process this to infer coarse user location (Country and City), and then discard the IP Address; the time; the make and model of your device (including operating system version); the version of the application being used; and information about your use of the application (we call this information “Zapalytics”). Information collected is not personal as it is

simply the user looking at the visualizations. Providing website: I have added the website to the follow up email. Amendment 2: Screen recordings will be collected via OneDrive (through my personal University of Waterloo account (r3woo@uwaterloo.ca)). Participants will have edit access to one folder named after their participant ID where they can upload their screenrecordings. Amendment 3: We are amending to record the entire Teams meeting (audio and visual) including the visualizations section. Participants are not saying personal information, notes may be taken as

Please upload any study materials related to the procedure(s)

Study material

DEMOGRAPHICS_REVISED4.DOCX

Study material

SURVEY QUESTIONS2.DOCX

Study material

INTERVIEW GUIDE_REVISED2.DOCX

Study material

NAME_ID_LIST.DOCX

Study material

DESIRABILITY TOOLKIT_V2.DOCX

Study material

ADDING OR REMOVING APPLICATION.DOCX

Study material

VISUALIZATION DESCRIPTIONS_REVISED3.DOCX

Study material

EMAIL SCRIPTS_REVISION2.DOCX

Study material

HOW TO USE ZAPWORKS2.PDF

Study material

ALLSURVEYS_FINALFORM_ANDWEBSITE_REVISION3.DOCX

Study material

HOW TO USE ZAPWORKS(1)-MERGED.PDF

Study material

VISUALIZATION SPECIFIC SURVEYS AND WEBSITE SCREENSHOTS.DOCX

Study material

PRE-STUDY MATERIALS SCREENSHOTS.DOCX

Study material

POST-VISUALIZATION SURVEY SCREENSHOTS .DOCX

D ed drug or natural health product?

No

Will you be collecting any biological specimens?

No

Will you be creating or contributing to a bio-bank, bio-repository, registry, as part of the study?

No

Will you be doing any genetic testing or analysis?

No

Incidental and secondary findings

See Guideline for reporting incidental and secondary findings to study participants

Are any of the methods or procedures used likely (i.e., a real possibility and probability) to reveal an incidental finding (i.e., discoveries made in the course of research but that are outside the scope of the research and/or results that are outside the original purpose for which a test or procedure was conducted)?

No

Are any of the methods or procedures used likely to reveal a secondary finding (i.e., findings that are not the primary target of the test or procedure; rather, it is an additional result that is actively sought)?

No

Equipment use

Will there be any equipment used as part of this study?

Yes

Please list all equipment being used in this study

Full name of device or equipment

Participant's Personal Smart Phone

What type of device or equipment is this

equipment or device that is approved for sale or use in Canada to be used with participants

Is this a medical device?

No

Select how you will be providing more information on the device/equipment

Please ensure your SOP explains the following:

Deception

Does the study involve deception or partial disclosure?

No

Risks and safeguards

Considering each method or procedure to be used in this study, indicate if participants might experience any of the following risks or harms

Psychological or emotional risks or harms (e.g., feeling demeaned, distressed, embarrassed, worried, upset, loss of self confidence, regret over the revelation of personal information, disruption of family routine)

Risk details

For each risk identified above, please add additional details describing that risk

Describe the risks or harm

There may be visualizations related to sensitive topics such as mental health. This information may be triggering for some participants. However, we will only be showing data related and relevant to the University of Waterloo community, of which the participants will be a part. Given this, it is likely that the harm is not more than the users will experience in their everyday lives.

Are any of the risks or harms identified above greater than those the participants might encounter in their everyday life?

No

A determination will be made, upon receipt of the application, if the research can be reviewed by delegated review or must be reviewed by one of the two Research Ethics Committees.

Describe the safeguards (or procedures) to be put in place to mitigate each of the risks or harms identified above.

There will be several parts of the visualization and participants will be know the topic of each visualization before they open it. Participants will be told ahead of time that they can opt out of any specific visualization. The topic of the visualization will be prominently displayed before participants open it.

For the risks or harms identified above, is there any monitoring that will need to be undertaken during the study?

No

Outline the criteria for stopping the study early due to safety concerns/other issues.

The study participant can stop the study at any time.

For the risks or harms identified above, is there any monitoring that will need to be undertaken following the study conclusion?

No

Privacy

Will demographic and/or background information be asked of participants?

Yes

What demographic/background information will be collected?

Age
Gender
Sex
Occupation
Education
Other

Describe what "other" demographic/background information will be collected.

Experience with Smartphones, which smartphone they have, experience with AR, experience with mobile AR, experience with VR. Relationship to University. major, program if relevant. We also ask the community contentedness questions with the demographics questions to get a baseline please see "Survey Questions 2" under methods and procedures for more details.

Will demographic/background information be collected separately from names and other identifying information?

Yes

Participant identification

Participants will be assigned an ID number.

If applicable how will the key/list that links participants' codes with their actual name and/or consent forms be stored and protected?

The document that links participant IDs and their names is stored separately from the data on a password-protected secure network.

Are there any limitations to the promise of confidentiality?

No

Will any study data be leaving the University of Waterloo, the province, or country (e.g., member of research team is located in another institution, province, or country, etc.)?

No

Will any collected data or information be entered into a database for future use?

Yes

Where will the data or information be stored?

The data collected from the study will be maintained on a password-protected computer database in a restricted access area at the University of Waterloo.

Who will be the custodian of the data or information?

The principle investigator will be the custodian of the data.

Who will have access to the database?

Researchers associated with this study will have access.

Indicate the measures in place to protect the confidentiality and security of the database.

The database will be password protected.

Are there other members of the research team who are not named on this application (e.g., co-op students, research assistants, or other temporary personnel) who may carry out specific tasks involved in your study?

No

Will individual participant identities be confidential in the publication or release of the study findings?

Yes

Data storage

What type(s) of data will be collected for this study?

Video-recordings
Electronic files

If identifiable features are captured, ensure this is described as part of the procedures section

For each type of information collected, identify where the data will be stored

The virtual records will be on a password protected computer, or password protected cloud account. After interview transcription has occurred and been manually verified the video recordings will be deleted.

For each type of data collected, identify the minimum retention period

All data will be archived after completion of the study and maintained for at least 8 years and then erased. After interview transcription has occurred and been manually verified the video recordings will be deleted.

Data Management

Are there plans to link the data collected with other data sets, databases, or registries?

No

The Tri-Agency Open Access Policy on Publications and some journals are requesting that research data be provided to an open access repository to promote the availability of findings, to enhance transparency and share with the widest possible audience.

Do researchers plan to make the anonymized data-set available in an online repository?

Yes

Identify the repository or database. If this is not yet know please state this.

Unknown.

Do you have a data management plan?

No

Data management planning is necessary at all stages of the research project lifecycle, from design and inception to completion. Data management plans are key elements of the data management planning process. They describe how data is collected, formatted, preserved and shared, as well as how existing datasets will be used and what new data will be created. They also assist researchers in determining the costs, benefits and challenges of managing data.

Consent and Withdrawal

Consent and Withdrawal

What member(s) of the research team will be responsible for obtaining informed consent?

Rachel Woo

Is there a relationship between the potential participant(s) and the person obtaining consent?

Yes

Explain the nature of the relationship (e.g., professor/course instructor, teacher, supervisor, employer, health care professional/physician, etc.)

Potentially friends, acquaintances and colleagues could participate in the study.

Describe how undue influence and/or authority to participate will be mitigated.

There is no undue influence, participants will not be obligated to participate there are no consequences to personal relationship or work relationship. The risk will be mitigated through not personally contacting anyone, they will have to voluntarily come forward to participate.

How will consent be obtained

Online consent (e.g., click one of two radio buttons)

Upload Information and Consent Materials

Upload Information and Consent Materials

CONSENT_FORM_REVISED5.DOCX

Study group

Upload Information and Consent Materials

INFORMATIONLETTER_REVISED5.DOCX

Study group

Do you anticipate that you will need to make special accommodations for your participant group?

No

Do you anticipate needing to put in place any special procedures when obtaining informed consent?

No

Will consent need to be re-documented throughout the life of this study?

No

Describe how participants will be informed of their right to withdraw from the study.

Participants will provide consent via the consent form which will provide details on how to withdraw their consent. Consent can be withdrawn until their data is anonymized for data analysis.

Outline what will be done with the participant's data if they withdraw from the study.

The participant's data will be permanently deleted.

Will any individuals taking part in this study be unable to provide their own informed consent?

No

Remuneration

Will there be remuneration provided to show appreciation for a participant's time, effort, skills, etc. to take part in the study?

Yes

Type of remuneration

Gift card

Identify the retailer(s) and dollar amount
$15 CAD gift card from Amazon

If a participant withdraws from the study will remuneration be pro-rated?

No, participants will receive maximum remuneration

Will participants incur any expenses by participating in the study?

No

Feedback and Appreciation

How will you show appreciation to participants for taking part in the study?

Participants will be remunerated as described above and thanked for their participation in the remuneration email.

When will feedback/appreciation be provided to participants (e.g., immediately after the session, at the end of a survey, mail results at time X.)?
We will provide feedback immediately after participation in the survey portion of the study as well as in the remuneration email.

Upload Feedback/Appreciation materials

Upload Feedback/Appreciation materials

FEEDBACKLETTER_REVISED4.DOCX

Study group

Upload Feedback/Appreciation materials

FOLLOW_UP_EMAIL_3.DOCX

Study group

Upload Feedback/Appreciation materials

5. HG - REMUNERATION AND SELF DECLARATION.DOCX

Study group

How can participants learn about the study results/obtain a summary of the findings if interested?

Participants will have the researcher's contact information and be able to reach out after completion of the study.

Other Details

Provide any other information relevant to this study you wish to explain to the Research Ethics Committee reviewers or to the staff in the Office of Research Ethics.

Other Attachments

Upload any additional study documents

Attachments

Attestation

As the Principal Investigator/Faculty Supervisor/Local Investigator, I attest to the following:

- I will ensure all co-investigators, collaborators, and student investigators listed on this application have reviewed the application contents and will conduct the study according to the application/protocol.

- I am aware that any changes made to the research must be reviewed and provided clearance before the changes are implemented. Change requests (i.e., an amendment) are to be submitted through the system. I am also aware ethics clearance for this study is valid for only 12 months unless I renew the study prior to the ethics clearance expiry date. If an annual renewal report is NOT submitted through the system prior to the expiry date, the study will be suspended, all work on the study must stop, and Research Finance will be notified which will result in a hold being put on the funds associated with this study.

- I agree to comply with the Tri-Council Policy Statement (TCPS2) for conducting research with human participants and with University of Waterloo policies and guidelines when conducting this study (e.g., statement on human participant research, IST policies, etc.).

- I confirm I have read the University of Waterloo Research Integrity guidelines and I agree to comply with the policies and guidelines of my profession or discipline regarding the ethical conduct of research involving humans.

By submitting this application I agree to the above attestations and will ensure the research is conducted accordingly

Only the Principal Investigator/Faculty Supervisor can submit the application. This acts as a signature indicating approval of the application.

This is the end of the application form. Click submit in the right menu if you are ready to send it to the Research Ethics Office.