“I’m not alone in that battle”: Designing Mobile AR for Mental Health Communication and Community Connectedness

Rachel Woo
r3woo@uwaterloo.ca
University of Waterloo
Waterloo, Canada

Daniel Harley
dharley@uwaterloo.ca
University of Waterloo
Waterloo, Canada

James R. Wallace
james.wallace@uwaterloo.ca
University of Waterloo
Waterloo, Ontario, Canada

ABSTRACT

For researchers at the intersection of health and human computer interaction, mobile AR presents a compelling platform for public health communication: it is increasingly available, highly customizable, and can present interactive visualizations of complex data. However, designers face challenges not only in adapting appropriate data and relevant public health metrics, but also in assessing their communicative potential and effectiveness for the target community. To contribute insight into this research area, we designed four mobile AR visualizations based on mental health issues and resources for our local university community. We then conducted a mixed-methods field experiment to investigate the impact of our AR visualizations on participants’ awareness and understanding of pressing health issues, and to document barriers to use in this context. We show that our visualizations increased participants’ sense of community connectedness and prompted them to reflect on their relationship with the university community. Based on these findings, we discuss opportunities for the field of human-computer interaction to further support public health communication.

KEYWORDS

augmented reality, public health communication, community connectedness, mental health, mobile AR

ACM Reference Format:
Rachel Woo, Daniel Harley, and James R. Wallace. 2018. “I’m not alone in that battle”: Designing Mobile AR for Mental Health Communication and Community Connectedness. In *Proceedings of ACM Conference on Designing Interactive Systems (DIS’24).* ACM, New York, NY, USA, 15 pages. https://doi.org/XXXXXXX.XXXXXXX

1 INTRODUCTION

As public health researchers continue to contribute insight into the mental health issues facing university students, there is a pressing need to ensure that students have the awareness, knowledge, and skills to benefit from those findings. While communication strategies for public health data have prioritized the broad reach of communication tools like the telephone, SMS, and video conferencing platforms (e.g., [66, 84, 92]), recent work has called for the use of technologies that help develop new skill sets, and that recognize the complicated emotions surrounding health [18]. We propose that for Canadian university students, mobile augmented reality (AR) presents a viable platform to respond to this need, leveraging participants’ access to technology and digital literacy to provide immersive, engaging, and impactful visualizations of relevant mental health data (e.g., [47, 58, 72]).

Using AR technologies for public health communication poses important challenges. Although researchers in the human-computer interaction (HCI) community have argued that AR and immersive visualizations can help 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” [51], adapting these insights for public health communication is not straightforward. Focusing on the needs of a specific community requires considerations around the selection of appropriate data, designing AR visualizations that interpret and personalize that data, and testing of visualizations in realistic real world contexts such as home use. These challenges suggest compelling opportunities to strengthen the connections between HCI and public health research, in which efforts to develop tools to communicate existing public health knowledge can result in new considerations for how these tools might be designed and assessed.

To contribute to this research area, we began by selecting public data about our local university community, focusing on mental health, chronic stressors, systemic issues, and resources. We then created four mobile augmented reality (AR) visualizations 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. Our visualizations used a variety of idioms like 3D, interactive representations of pie charts, timelines, and a campus map — all experienced using a personal mobile device. We then conducted a field study where we asked 17 participants to try the visualizations at home, followed by a semi-structured interview and a set of questionnaires. Questionnaires included the reflection inventory [8], the Microsoft Desirability Toolkit [7], and a relevant public health measure called the Community Connectedness Scale [29], which we adapt to respond to recent calls in the visualization community to find meaningful measures for evaluation [87].

Our study provides insight into how mobile AR can be used to communicate mental health data for a university community, which has implications for both public health and human-computer interaction research. Leveraging the concept of community connectedness, the results of our study provide a proof-of-concept that mobile AR

DIS’24, July 2024, Copenhagen, Denmark

ACM ISBN 978-1-4503-XXXX-X/18/06…$15.00
https://doi.org/XXXXXXX.XXXXXXX

can be used by public health practitioners as a health communication tool and/or as an intervention. Ultimately, our work calls for human-computer interaction research to help develop new methods of communicating public health knowledge that provides participants with an opportunity to reflect on data about themselves and their community.

In summary we present:

(1) The design process of four visualizations that explore how mobile AR might be used to engage students in conversations about mental health
(2) Results from a field study that demonstrate how our visualizations may increase one's sense of community connectedness and awareness of community health concerns
(3) Considerations for how public health research and relevant tools can be used to inform the design of technology, and vice versa.

2 RELATED WORK

In this section, we briefly review two areas of related work. The first offers an overview of the needs for public health communication within the context of our research, which reveals an opportunity to explore mobile AR as a communication tool within a university community. The second reviews how research within fields related to HCI have explored the possibility of using visualizations and AR, which ultimately suggests an opportunity to leverage public health research to extend the ways we assess social connectedness.

2.1 Opportunities for public health communication in universities

Canadian universities are currently experiencing a student mental health crisis [70]. In 2016 42% of students met the criteria for clinical psychological distress [73]. Robinson et al. [73] have identified several factors that prevent students from using resources, with some students "feeling uncomfortable accessing services" (28.7%) and some "thinking counselling services would not help" (11%). Additionally, 18.5% of students indicated that they did not know how to access services [73]. These types of challenges suggest a clear and pressing need for improved health communication tools. As health researchers strive to examine how they might better engage students in conversations about mental health (e.g., [17, 44, 74, 82]), communication tools would ideally help to normalize access to mental health resources, and provide increased awareness of the support that universities currently offer.

Health communication, broadly defined, seeks to "engage, empower, and influence individuals and communities" [p. 5] to improve their health and quality of life [80]. In short, health communication seeks to help the public adopt learnings and best practices from the medical community. It is a complex, multidisciplinary field that takes into account an individual or community's lifestyle, concerns, beliefs, attitudes, social norms, and barriers to change. Its key characteristics — much like human-centered design familiar to HCI researchers — include being people-centred, evidence-based, and audience- and media-specific [63, 80]. For a university community, this would mean catering the design and deployment to meet the specific needs of current students in real-world settings. Moreover, because stronger connections to community are said to lead to a higher likelihood of better mental health overall [64], an important question within this context is how communication tools might also help to maintain a sense of belonging and a sense of connection within that community.

Traditionally, health communication professionals have focused on low-tech interventions, like paper brochures or word of mouth campaigns. Technological interventions typically focus on low-cost and pervasive technologies like SMS (e.g., [66]), with the telephone and videoconferencing frequently being used in public health research [84, 92]. While these strategies are effective for a general population, the digital literacy and widespread use of smartphones among Canadian university students suggests an opportunity to explore additional forms of media to help foster connection and communicate relevant mental health data.

2.2 Opportunities for human-computer interaction in public health communication

Recent work has suggested that immersive visualizations (such as those that use augmented reality) may be an effective strategy to communicate and personalize data (e.g., [47, 58, 72]), and prior work in HCI has explored the design and development of many technologies that could support a range of visualizations. Examples include the use of tablets, smartphones, and wearables to physically explore 3D spaces (e.g., [38, 43, 69, 72, 78]); or visualizations for augmented (e.g., [9, 89]) and virtual (e.g., [23, 76]) reality applications; or use cases for novel, cross-platform authoring and prototyping tools to create visualizations [47, 79]. However, a critique of this body of work has been its limited engagement with its intended audience [14], suggesting that an approach that targets deployment within a specific community may offer insight into how such technological interventions meet real world needs.

HCI research has also shown a longstanding interest in understanding and designing for feelings of connectedness, particularly as a means of improving health and wellbeing (e.g., [3, 5, 31]). In pursuit of these goals, HCI researchers have explored how technologies like audio and video [10], robots [37], chatbots [85], social media [60, 85], and wearables [24], might facilitate various forms of prosocial connection. While there are examples of projects that target specific groups like families [15, 75], older adults [37, 81], online learners [86], or co-workers [88], these efforts point to a broader need to examine the complexities of real-world deployment. For example, although some visualization research strives to "represent data about people in a way that is intended to promote prosocial feelings" [56], particularly for immersive media like augmented reality, there is an ongoing need to better understand how data visualizations can foster a sense of connectedness across specific and/or targeted communities (e.g., [26, 51]).

With a growing interest in bridging the health and technology research communities "to create more engaging, accessible, scalable, and timely interventions" [49], one broader challenge of applying related work in HCI to help support social belonging is navigating a variety of strategies, definitions, and measures. For instance, Visser et al. [85] define *social connectedness* as "a short-term experience of belonging and relatedness" [p. 4438], mirroring work by Mittmann et al. [55] in the classroom. Similarly, Folstad et al. [28] define *relatedness* as "closeness and connectedness to significant others"

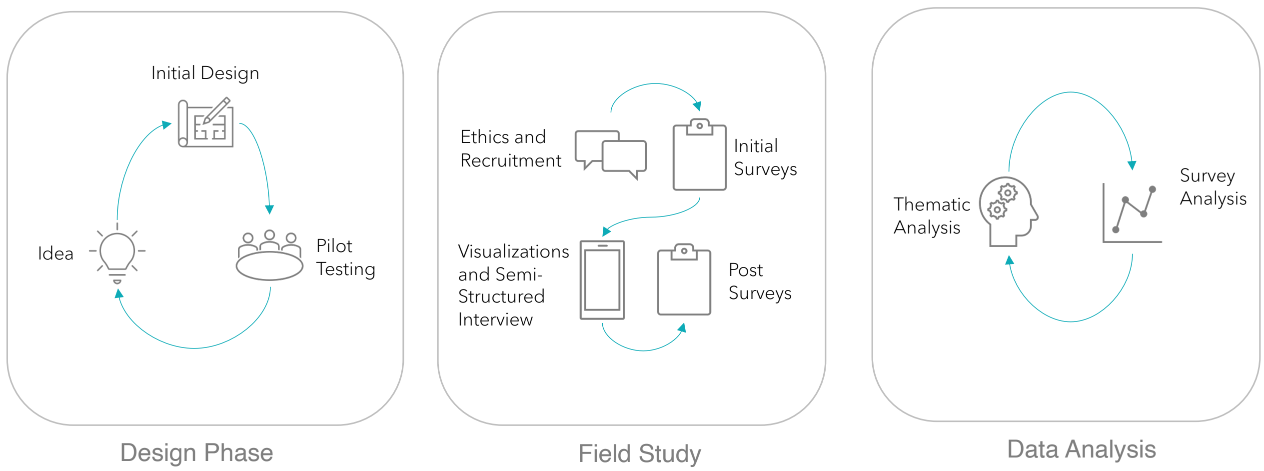


Figure 1: Our research process comprised three phases: design, field study, and analysis.

[p. 3]. While some research has engaged qualitatively with social connectedness (e.g., [3]), these efforts suggest an opportunity to draw from relevant measures in health research to strengthen the connections between existing strategies in public health and HCI.

3 OVERVIEW OF OUR RESEARCH PROCESS

An overarching goal of our research is to examine how mobile AR visualizations might offer additional opportunities for public health communication, with a focus on communicating mental health data to university students. Prior work suggests an opportunity for improved mental health communication tools that 1) respond to current needs in mental health communication by leveraging visualizations with relevant data, and 2) apply the design to real-world contexts while leveraging appropriate health measures to better understand how the design might apply to a specific context of use. We therefore began our research process by designing AR visualizations using real data about our local university community. Alongside more conventional usability assessment tools, we identified a public health metric called the Community Connectedness Scale [29] (we describe our rationale for using this scale in subsection 5.1). Finally, we tested our AR prototypes in a field study. Our field study was conducted in participants' homes, exploring how community members interacted with and responded to mobile AR visualizations displaying community health information. This approach allowed us to investigate under-explored contexts for field test research such as personal mobile HCI [40] and the home as a testing ground [21].

Overall, our research process included: (1) a Design Phase, (2) a Field Study, and (3) Data Analysis (Figure 1), guided by the following research questions:

- ***Research Question 1:*** How might we use mobile AR visualizations to communicate mental health research and resources?
- ***Research Question 2:*** Can viewing that information improve feelings of community connectedness?
- ***Research Question 3:*** How might public health research and tools be used to inform the design of technology?

As shown in Figure 1, we began with a *Design Phase* comprising of ideation and the technical implementation of four AR visualizations, followed by pilot testing activities (RQ1). Our prototypes functioned as a proposal rather than a prediction [90], enabling us to explore different visualizations, to iteratively fine-tune each design, and to document that process and describe how different constraints shaped our design [22]. Second, after identifying and adapting the Community Connectedness Scale [29], we conducted a mixed-methods *Field Study* to assess our prototypes in community members' homes.

Although human-computer interaction research does not always benefit from formal evaluation [2, 34], evaluating our prototypes in this way is not only a valuable way to gain early feedback [33, 62, 68], but is also an opportunity to draw stronger connections to gaps articulated in public health research. In our *Data Analysis*, we used codebook thematic analysis [13] of interview data and pre/post tests and descriptive statistics of questionnaires administered during the study. By triangulating quantitative survey data with qualitative feedback from semi-structured interviews we describe how the visualizations increased participants' feelings of community connectedness (RQ2). Taken together, the research process provided a basis to reflect on what lessons this work provides for the development of health communication technologies that bridge the fields of public health and HCI (RQ3).

4 DESIGN PHASE

Targeting our own community in our efforts to communicate public health data with mobile AR visualizations required initial design choices related to the technologies our community members have access to, and related to the mental health data that we chose to visualize. We chose to visualize data from the 2019 National College Health Assessment II (NCHA-II), an international, validated survey on student health, which includes data collected from our university community. Importantly, although our university community has access to this data, the only way to view the results is by downloading an 18-page executive summary available as a PDF on our university's website. No visuals are provided in this document, so our conceptual design phase included considerations for what aspects of the data we would select and represent in our visualizations.

For technical implementation, while it is reasonable to predict that nearly all students on our campus own a personal smartphone [16], we cannot expect that these are the latest models capable of displaying the state-of-the-art in AR visualizations. This created an important design constraint, with our work ultimately attempting to balance the design of AR visualizations that could be effectively viewed on older devices. However, using personal devices also offered an opportunity to develop visualizations that participants could view in their own homes and personal spaces. This section describes how our design responded to these considerations from conceptual design to implementation.

4.1 Conceptual Design and Pilot Testing

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 NCHA-II and then designing visual metaphors to communicate that information. Each visualization went through several rounds of conceptual changes after informal feedback from lab members as we worked to find the most appropriate data and visual metaphors.

We focused on visualizing statistics related to common issues that students may face on a daily basis, according to the most recent NCHA-II survey. For participant safety, we did not include information with regard to self-harm or suicide. We also avoided talking about specific mental health diagnoses as we did not want participants to feel pressured to disclose sensitive mental health information.

Since a goal of our visualizations was to explore the potential of mobile AR in a field study, we intentionally included a variety of visualization idioms [57]. We included traditional visualizations like 3D charts and maps as well as idioms from the research community like anthropographics [12] and immersive scatter plots [42, 71]. Conceptually, we felt that these choices would serve as a reasonable design probe and were representative of the types of visualizations in the HCI literature and infographics often distributed by public health practitioners. By including a variety of designs, participants in our field study would be better able to compare, contrast, and comment on visualizations deployed in mobile AR [36].

After developing an initial set of prototypes we conducted three pilot tests with informal feedback from members of our lab to refine our design choices and to test the application in different locations. The lab members used the prototype visualizations and then participated in an informal interview about improvements to the design and content. These informal interviews focused on ensuring that the visualizations were interpretable, usable, and understandable. This involved asking questions about how the data was communicated, whether the visualizations could be viewed easily in different environments, as well as ensuring the overall messaging was clear. Valuable feedback was provided on adapting the visualizations to various locations, ensuring the interface worked on all phones, assessing the content of the visualizations and phrasing of the instructional text, and strategies to remove ambiguity of interpretation.

4.2 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, (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.

4.3 Prototype Visualizations

At the end of our design phase, we had created four conceptually-linked visualizations (Figure 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 its ZapCode to open it on their smartphone. They then place the visualization in their environment using floor-tracking, and can explore it by physically navigating the space.

V1: Diversity of People and Health Needs on Campus shows who is a part of the community through 3D pie charts of student demographics. The five pie charts show categorical breakdowns of age, sexuality, student status, ethnicity, and gender. The pie charts are presented in a circular layout, distributed around the viewer, and invites participants to physically explore the charts by walking around them to learn about the diversity of students and health needs present in the community. We chose to use pie charts over more accepted idioms like bar charts because we found that the circular layout was more conducive to this physical navigation, and accuracy of interpretation was not our primary concern [57].

V2: Student Mental Health Issues 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." 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,

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

responses are represented by silhouettes of people, in a nod to anthropographics [12]. 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 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 2,781 student responses were represented through a 3D polygon are stacked into columns that physically represent how many people in the community struggle with these issues. With this visualization, we chose to explore how large virtual representations of the data can be used to emphasize the magnitude of existing health issues in on campus.

V4. Student Resources for Community and Mental Health directs students to 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. An accompanying website provides details on demand for each resource, such as who can access it and what services it offers. We chose to include a map to prompt participants to reflect on how visualizations used on a daily basis might translate to mobile AR, and the map layout fit well with our needs to visualize services available to the university community that was primarily located on a central campus.

5 FIELD STUDY

We evaluated our visualizations in a mixed-methods field study. The field study enabled us to engage members of the university community in the research process, and provided an opportunity to collect quantitative and qualitative data about our mobile AR visualizations. To develop considerations for how this work might leverage evaluation efforts across public health and HCI, we chose data collection tools across both areas, which resulted in our interest in using the Community Connectedness Scale [29] alongside metrics that evaluated participants' experiences with the AR application. Overall, we wanted to understand how our visualizations might be experienced by members of the community (RQ1), to develop a preliminary understanding of their impact on community connectedness (RQ2), and to better understand what lessons we might learn when striving to bridge efforts in public health and HCI (RQ3).

Field tests were a particularly compelling way to answer these questions, since they also enabled us to develop insight with members of the university community in their homes using their personal smartphones. These factors add important contextual nuance to the study. Using commodity hardware in settings that may not be optimally configured for AR presents important parallels for real-world deployment. For example, participants may not have space to engage with the visualizations, and we can make no assumptions about available space, lighting, or other environmental factors. Additionally, because we conducted the field study during the emergency phase of the global SARS-CoV-2 pandemic it was not only safer to conduct the study in participants' own homes, but could also provide insight to the ways that community members might think about connectedness even when they are not on campus.

This section begins with a brief overview of our choice to focus on community connectedness, followed by a description of our recruitment, study procedure, and our strategy for data collection and analysis.

5.1 Evaluating Feelings of Community and Community Connectedness

While community connectedness can be defined in many ways (e.g., [29, 77]), all definitions 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, and perceived safety. Importantly, it is a *protective* health factor [6, 39, 61]. That is, it is a characteristic that is associated with reduced and/or lower likelihoods of negative health outcomes. It 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.

Because of its utility for understanding health and developing interventions, several measures have been used to assess community connectedness. The Sense of Community Index (SCI) [48] has been used to assess community connectedness, but its utility and validity have been questioned by the psychology community (e.g., [27, 67]). In response to those questions, Cope et al. [19] 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 [52] provide a single item, pictorial, 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.

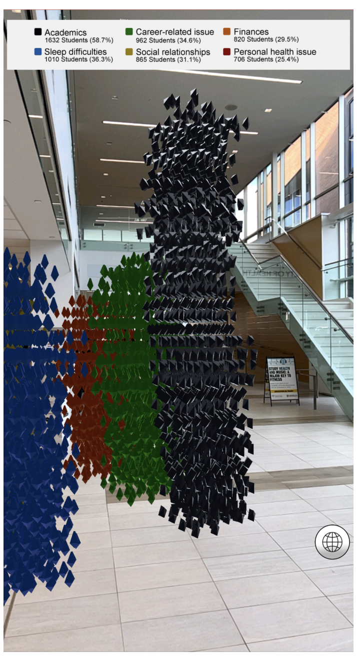
Despite these challenges, scales created for specific groups appear to present promising assessment opportunities. The Community Connectedness Scale [29] was developed to understand community connectedness within an LGBTQ+ community in New York City, and was later adapted for a broader context [30]. It comprises eight 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 [29]. Based on these strengths, we chose to adapt this Community Connectedness Scale to understand how technology might be designed to foster community connectedness for university students. In practice, this was a simple procedure, removing two questions that were not relevant to our target population and adjusting the text of other questions to reflect the university context.

5.2 Participants

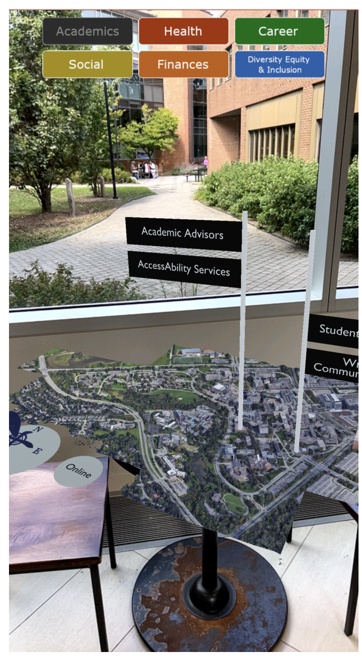
We recruited 17 participants from the university community who were fluent in English and who owned a compatible smartphone (Table 1). Two potential participants were excluded because they did not have a phone with an updated version of the OS. Our final pool included: 5 men, 1 non-binary person, and 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

(V1) Diversity of People 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 2: We developed four mobile AR visualizations using the Zappar app to explore how visualizations of community mental health data might help to build community awareness and connectedness.

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 1: A summary of participant demographic data from our field study.

7 reported having 'some experience' for both technologies. 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).

5.3 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 1 m^2 well-lit space in which to complete the study. Participants also completed a demographic questionnaire, a questionnaire assessing previous experience with virtual environments, and our modified Community Connectedness Scale [29].

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 viewed all four visualizations they completed the Community Connectedness Scale [29] again, followed by the Reflection Inventory [8], and the Microsoft Desirability Toolkit [7]. 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 lasted approximately 30 minutes. Participants were then asked to send their screen recordings to the researcher via Microsoft OneDrive. Finally, they were thanked for their time and provided $20 CAD for their participation.

5.4 Data Collection and Analysis

Our main data collection tools were: (1) the Community Connectedness Scale [29], (2) the Reflection Inventory [8], (3) Microsoft Desirability Toolkit [7] and (4) semi-structured interviews. The MS Desirability Toolkit comprises 118 descriptive words that can be selected by participants to help them elucidate their experience when using software prototypes. Based on our 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 codebook thematic analysis [13] to analyze our interview data. Our goal was to describe what was said by participants about their sense of community to contextualize the quantitative findings from our Community Connectedness Scale, Reflection Inventory, and Desirability Toolkit. Interviews were audio and video recorded by Microsoft Teams with auto-transcription enabled. The first author then manually verified and corrected the automatically generated transcriptions before de-identifying them. 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.

6 RESULTS AND DATA ANALYSIS

Our results include responses to the reflection inventory, changes to community connectedness, and responses to the MS desirability toolkit. We then include qualitative data from the thematic analysis to develop three overarching themes based on the semi-structured interviews.

6.1 Quantitative Results

6.1.1 Reflection Inventory. Responses to the Reflection Inventory (Figure 3) indicated that participants felt that the visualizations prompted them to reflect on their relationship with their community. The median participant 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).

6.1.2 Community Connectedness Scale. 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 performed Wilcoxon signed-rank tests for differences in each questionnaire item.

We found significant post-study 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: $V = 34, p = 0.4374$). A summary of these results is shown in Figure 4.

6.1.3 Microsoft Desirability Toolkit. We also used Microsoft's Desirability Toolkit [7] to assess participants' experience with our visualizations. Participants could select any number of words from a 25 word list that included both positive and negative descriptors. In total, 103 words were selected by the 17 participants: 82 positive and 21 negative (Table 2). Nearly 80% of all words chosen were positive, and only 3/17 participants (P4, P6, P8) used 50% or more negative words (e.g., "annoying").

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 2: Summary of participants' responses for the Microsoft Desirability Toolkit.

6.2 Thematic Analysis

Our thematic analysis of interview data helped us to understand participants' use of mobile AR, and we developed three themes (Table 3): awareness and reflection, a sense of belonging, and mobile AR in the home. We now present each of these themes:

6.2.1 Awareness and Reflection. Participants described the visualization experience as novel, memorable, and as allowing them to interact with the data in a unique manner. P5 described this memorability by comparing to paper handouts typically used in public health communication, "So it's not something I would forget like handouts and stuff. I always forget after [handouts] ... [but] this is a unique experience. I don't think I could forget this data." For P9, the mobile AR platform made data more tangible, saying that "seeing it right there, right in front of you, it's as if you could almost touch the data." Together, these comments underline how mobile AR can provide a compelling contrast to conventional forms of public health communication, prompting a view of the data as something close, physical, and experiential.

Some participants also commented on how the visualizations prompted them to stop and reflect on the community and their issues, and how the revelations sometimes surprised them. Their reflections put the data into conversation with their own expectations and experiences. For instance, P10 was surprised by how prevalent academic issues were for student mental health, "OK, so around 58%, 59% of students feel like academic is so difficult or very difficult. That's kind of shocking." P10 was then surprised by how infrequently financial issues were raised among community members, "Finances, only 29.5% [of] people ... I feel that number is low. It's just 820 students out of 2481, which is 20% of the students and I felt it would be a bigger number." We interpret these observations as indicative that beyond being a novel experience, the visualizations resulted in some internalization of the data by offering participants an opportunity to evaluate that data against prior knowledge.

Participants' reflections also showed an ability to develop nuanced interpretations across data sets. For example, participants recognized that an individual's background — like their online status or citizenship — might relate to differences in experience with mental health. P17 stated, "I mean it depends, right? What kind of stress people are facing. If it's a 20 year old person, the mental health issues are completely different if someone is in their 50s doing [a] PhD or graduate studies. I mean, I feel like it has to be differentiated if it's someone who was born in Canada or someone who came as an international student." These sorts of feelings were corroborated by other participants, such as P12 who stated, "It's difficult to keep up with the academics and especially the finances as well because

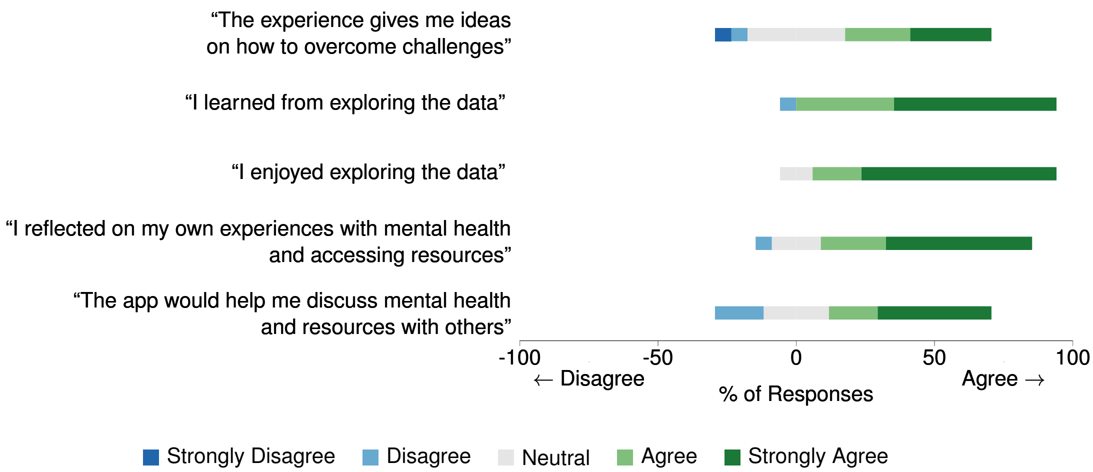


Figure 3: Summary of Reflection Inventory responses, based on 5-point Likert scales.

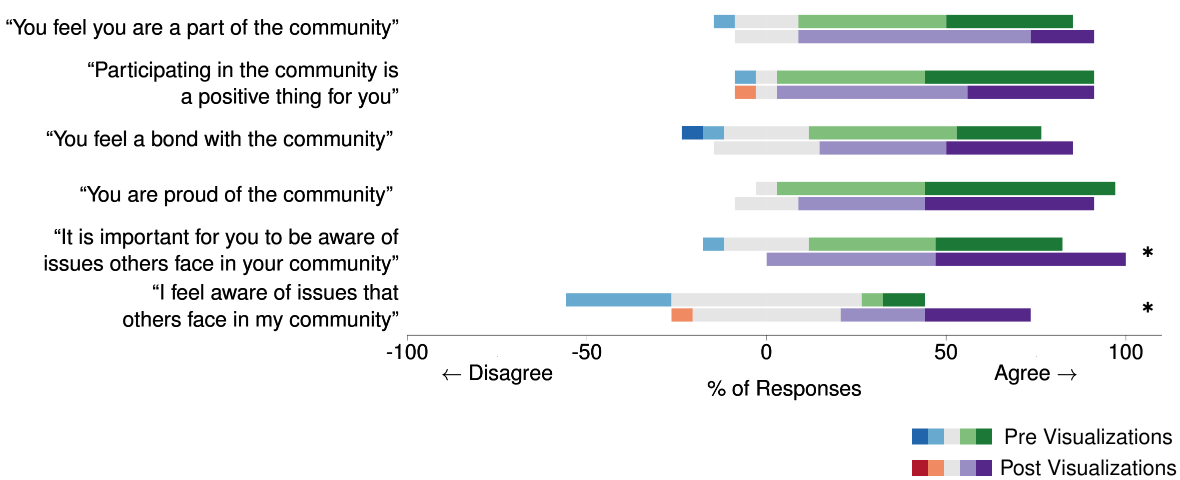


Figure 4: Summary of Community Connectedness Scale responses, based on 5-point Likert scales. Wilcoxon signed-rank tests revealed significant differences between pre- and post-tests for "It is important for you to be aware of issues others face in your community" (CC5) and "I feel aware of issues that others face in my community" (CC6).

Theme	Description
Awareness and Reflection	How participants reflected on their experiences in the community, learned about the people within it, and reflected on the similarities and differences from themselves.
A Sense of Belonging to their Community	How the mobile AR visualizations fostered a sense of belonging to the university community and their emotional reaction to other people's experiences in the community.
Mobile AR in the Home	How participants felt the visualization could be improved, or limitations of mobile AR as a technology within real-world contexts. For example: difficulties with navigation, or feeling the prototype is low-fidelity.

Table 3: A summary of the three main themes generated during our thematic analysis of participant interviews.

I am an international student as well. And I know how expensive [the university] is." These examples show how individuals used the visualizations to think through their interpretations, ultimately concluding with an appreciation for the ways that specific groups are impacted differently within the university community.

6.2.2 A Sense of Belonging to their Community.

Overall, many participants expressed a sense of connectedness with their peers while exploring the visualizations. A common reflection was the sense that those represented by data reminded participants of themselves, prompting some participants to see the value of the visualizations as a tool to foster connection. P7 said, “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.” As they reflected on the data they were viewing, and how it represented themselves and their community, participants often felt a sense of relatedness, camaraderie, or belonging.

Participants also noted feeling more connected to the institution and physical space. P9 explained how the visualizations helped them to overcome a sense of disconnect arising from remote learning during the pandemic, “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 the data visualized, I did feel more connected here as a student.” Other students with more experience on campus also felt this sense of connection. For example, P7 said, "I especially like the last map part. It almost like felt like I'm in campus and I could easily understand . . . and I could relate to all the experiences I had, all the resources I used and where I went for and yeah, that last part was really good." These perspectives illustrate how the visualizations fostered feelings of belonging by evoking a shared experience and a shared sense of place.

6.2.3 Mobile AR in the Home.

The variety of homes and environments that participants used highlighted the ways that mobile AR would need to better respond to real-world deployment. Although they were instructed to physically move around the visualization, some did not. P14 explained that physically engaging with the visualization would be difficult in their environment: “For instance, if there was something against the wall . . . I can't see the other half of the graphic because it's against the wall.” Such instances suggested opportunities for visualizations that might better adapt to different environments, different levels of experience with AR applications, and different physical needs. While our participants did not comment on their own physical accessibility needs, we noted that broader deployment would also require alternate and customizable modes of interaction.

Although our participants were positive about mobile AR overall, prior experience with immersive environments and technologies appeared to affect their expectations. Some participants had experience with headset AR/VR and felt that mobile AR was outdated. For example, P8 and P12 suggested they would have preferred headset VR. By contrast, P17 expressed the opposite, arguing that even mobile AR could be a barrier to broader adoption: “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 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." This highlights the fact that immersive technologies are still not widely adopted. In our study, only 41% of participants had ever used mobile AR or headset VR. As with our overall design goals, this participant insight offered a reminder that while mobile AR might be an effective communication platform for some, there is a need to understand and support the specific technological needs and digital literacies of everyone in the target community.

7 DISCUSSION AND IMPLICATIONS

Our research was motivated by a need for better health communication tools and our findings point to the potential of mobile AR to fulfill this need. In particular, our research process has enabled us to explore how mobile AR can be used to communicate mental health research and resources (RQ1), to show that viewing such information can improve feelings of community connectedness (RQ2), and how public health research and tools can be used to inform the design of technology (RQ3). We now reflect on the implications of our findings and on our three design questions:

7.1 (RQ1) How can we use mobile AR to communicate mental health research and resources?

Our quantitative data indicate that participants enjoyed interacting with the mobile AR visualizations. Participants' responses to the Reflection Inventory were nearly all positive, particularly for items like ‘I enjoyed exploring the data’ and ‘I learned from exploring the data’. Moreover, responses to the Microsoft Desirability toolkit corroborate these positive experiences through common descriptors like ‘creative’, ‘engaging’, ‘meaningful’, and ‘useful’. These perceptions were also reflected in our interview data, with participants commenting on the visualizations' novelty and memorability, particularly when compared to paper resources.

Although research on mobile AR has largely focused on technical contributions (e.g., [14, 26]), we have shown its potential as a public health tool. Our research process demonstrated how immersive, mobile AR visualizations might be used to increase feelings of community. Our field study demonstrated our mobile AR visualizations have the *potential* [41] to help engage community members and to communicate relevant public health data. 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 mobile AR as a useful tool for education and health promotion. That is, 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. [51].

A natural question is whether our mobile AR would be more or less effective in evoking these differences than, for example, paper-based visualizations or 2D mobile visualizations of the same data. While we have shown some degree of utility, the *efficacy* and *efficiency* of mobile AR as a public health tool remain to be shown. These questions are particularly salient given related concerns in the HCI and data visualization communities: there are many challenges in designing mobile and/or 3D visualizations for effective communication (e.g., [45]), and there is an ongoing need to test taken-for-granted design principles for visualizations (e.g., the use of 'chart junk' for improving memorability [4]). We intentionally did not conduct a comparative study, and instead chose to engage in a design exercise within this complex research context — but given the potential we have now identified in our field study, future comparative work would be a logical next step.

7.2 (RQ2) Can mobile AR improve awareness and increase community connectedness?

Overall, our 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, $p = .03301$). These findings point to the potential efficacy of mobile AR visualizations as a medium to increase awareness of one's community.

We did not observe differences in the other items of the Community Connectedness Scale. 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, the 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.

To our knowledge, and despite recent interest in understanding how to design more human-centred visualizations (e.g., [12, 56]), community connectedness has yet to be explored in the human-computer interaction community. Our study shows how adaptations of the Community Connectedness Scale [29] might be used to measure and understand changes related to the use of visualizations — particularly in social computing research where one's sense of community may be a focus of study. Importantly, the needs of the human-computer interaction community differ from those of other fields like psychology (e.g., [19]), 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. To develop such tools, there is a need to establish scale validity through future work, and to develop an understanding of how they might be applied to active areas of research like social networks (e.g., [1, 32]), games (e.g., [17, 59]), or 'the metaverse' (e.g., [83]).

7.3 (RQ3) How might public health research and tools be used to inform the design of technology?

Our work was motivated by calls from the human-computer interaction community to bridge health and technology research (e.g., [49]), and the recognition that some areas of technology research have had limited engagement with the target audience [14]. We therefore intentionally set out to engage with the intended audience for our mobile visualizations to develop insight into their design and use as potential health communication tools. Key themes of our investigation are that personal identity and self-reflection played important roles in how people engaged with mobile AR, especially when providing opportunities to reflect on how their own experiences were different from and/or similar to that of other community members.

Our participants' self-reflection suggests a need to continue to explore how factors like gender [50], culture [46], and identity [35, 65] influence our experiences across immersive technologies and study design. For instance, some participants' responses suggested an opportunity for higher granularity of demographic data with respect to socio-economic and mental health information, as well as more in-depth examinations of lived experience. Our thematic analysis provides a reminder that real-world contexts and lived experience can deeply impact how people engage with immersive visualizations, and that there is a need to better understand how these conditions might shape the use of such visualizations. Our work aimed to better understand how students react to and understand personalized health information, exploring a new application area for immersive visualization [25].

Finally, our work suggests opportunities to emphasize the synergy between health-based research on community connectedness as a social determinant of health (e.g., [11, 29, 53, 54, 77]) and human-computer interaction research that seeks to foster various forms of connectedness (e.g., [26, 51]). Researchers have coined the term 'anthropographics' [12] as "visualizations that represent data about people in a way that is intended to promote prosocial feelings" [56]. Correll [20] writes 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]. Our work demonstrates a similar need and the potential for cross-pollination between the health and human-computer interaction communities.

7.4 Limitations and Future Work

We explored how to improve community connectedness through immersive visualization of mental health data. This exploratory approach enabled us to ask how we might take into account many factors such as public health best practices, technological constraints, and social dimensions of visualization and communication. Our goal was to create *extensible* knowledge [36] 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 [90]. Despite these strengths, our research also has several limitations that are worth discussing:

As our approach was exploratory it was intentionally not comparative, and so we cannot know which of our four visualizations, or if a certain combination of them were effective, or if any of the visualizations may have independently *decreased* community connectedness. 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. This approach is consistent with best practice for human-computer interaction (e.g., [41]) and design-based research (e.g., [90, 91]) processes, but points to a need for future work to more closely examine the trends we have identified.

There is a necessary degree of specificity in designing mental health education for the university population. Although this group offers rich data and a technologically literate community, we cannot expect that our results would hold outside of a dominantly western, young, and highly educated population [46]. Indeed, our findings underscore the importance of improved understandings of contextual factors like an individual's identity, role within the community, health, or finances. These aspects point to additional opportunities for future work, both in terms of additional layers of complexity for university communities, and to test mobile AR visualizations designed to meet the needs of other communities.

Our use of the Community Connectedness Scale [29] also suggests areas for future work. Targeting the university community and the pre-/post-intervention testing were 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., [19, 27, 67]), but have yet to be developed for research communities interested in technology design. 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. We expect that as interest in designing for community connectedness increases, that more appropriate and descriptive tools may be required, or that designers may use a variety of scales to unpack facets of physical, mental, and social well-being.

8 CONCLUSION

Our work demonstrates how mobile AR visualizations can be used to effectively communicate existing mental health data and resources. Our field study showed that this approach can elicit positive changes in community connectedeness, 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 results suggest opportunities to leverage mobile AR visualizations as a public health tool, while also emphasizing the need for data collection that foregrounds the contexts and experiences of community members. Overall, this study motivates the need for additional research by the human-computer interaction community to continue exploring how mobile AR visualizations might be used to improve public health knowledge and awareness. Given the ongoing need to communicate public health information, we assert that these contributions and methods offer important insight into how we might apply strategies that bridge the human-computer interaction and public health research communities.

ACKNOWLEDGMENTS

We thank the University of Waterloo Games Institute and its members for their constructive feedback. This work was made possible by the Natural Sciences and Engineering Research Council of Canada and in particular NSERC Discovery Grant 2022-03268.

REFERENCES

[1] Tawfiq Ammari, Sarita Schoenebeck, and Daniel M. Romero. 2018. Pseudonymous Parents: Comparing Parenting Roles and Identities on the Mommit and Daddit Subreddits. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3173574.3174063

[2] Kristina Andersen, Andy Boucher, David Chatting, Audrey Desjardins, Laura Devendorf, William Gaver, Tom Jenkins, William Odom, James Pierce, and Anna Vallgårda. 2019. Doing Things with Research through Design: With What, with Whom, and Towards What Ends?. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3290607.3299011

[3] Amid Ayobi, Rachel Eardley, Ewan Soubutts, Rachael Gooberman-Hill, Ian Craddock, and Aisling Ann O'Kane. 2022. Digital Mental Health and Social Connectedness: Experiences of Women from Refugee Backgrounds. *Proc. ACM Hum.-Comput. Interact.* 6, CSCW2, Article 507 (nov 2022), 27 pages. https://doi.org/10.1145/3555620

[4] Scott Bateman, Regan L. Mandryk, Carl Gutwin, Aaron Genest, David McDine, and Christopher Brooks. 2010. Useful Junk? The Effects of Visual Embellishment on Comprehension and Memorability of Charts. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA) *(CHI '10)*. Association for Computing Machinery, New York, NY, USA, 2573–2582. https://doi.org/10.1145/1753326.1753716

[5] Roy F Baumeister and Mark R Leary. 1995. The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological bulletin* 117, 3 (1995), 497.

[6] C Bell, AV Pham, and JS Carlson. 2011. Protective factors. *Encyclopedia of Child Behavior and Development* 25, 6 (2011), 10–11.

[7] Joey Benedek and Trish Miner. 2002. Measuring Desirability: New methods for evaluating desirability in a usability lab setting. *Proceedings of Usability Professionals Association* 2003, 8-12 (2002), 57.

[8] Marit Bentvelzen, Jasmin Niess, Mikołaj P. Woźniak, and Paweł W. Woźniak. 2021. The Development and Validation of the Technology-Supported Reflection Inventory. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 366, 8 pages. https://doi.org/10.1145/3411764.3445673

[9] Mark Billinghurst, Raphael Grasset, and Julian Looser. 2005. Designing Augmented Reality Interfaces. *SIGGRAPH Comput. Graph.* 39, 1 (feb 2005), 17–22. https://doi.org/10.1145/1057792.1057803

[10] Sara A. Bly, Steve R. Harrison, and Susan Irwin. 1993. Media Spaces: Bringing People Together in a Video, Audio, and Computing Environment. *Commun. ACM* 36, 1 (jan 1993), 28–46. https://doi.org/10.1145/151233.151235

[11] Jessamyn Bowling, Jordan Barker, Laura H Gunn, and Tatim Lace. 2020. "It just feels right": Perceptions of the effects of community connectedness among trans individuals. *PloS one* 15, 10 (2020), e0240295.

[12] Jeremy Boy, Anshul Vikram Pandey, John Emerson, Margaret Satterthwaite, Oded Nov, and Enrico Bertini. 2017. Showing People Behind Data: Does Anthropomorphizing Visualizations Elicit More Empathy for Human Rights Data?. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 5462–5474. https://doi.org/10.1145/3025453.3025512

[13] Richard E. Boyatzis. 1998. *Transforming qualitative information: Thematic analysis and code development.* Sage Publications, Inc, Thousand Oaks, CA, US.

[14] Nathalie Bressa, Henrik Korsgaard, Aurélien Tabard, Steven Houben, and Jo Vermeulen. 2022. What's the Situation with Situated Visualization? A Survey and Perspectives on Situatedness. *IEEE Transactions on Visualization and Computer Graphics* 28, 1 (2022), 107–117. https://doi.org/10.1109/TVCG.2021.3114835

[15] A.J. Bernheim Brush, Kori M. Inkpen, and Kimberly Tee. 2008. SPARCS: Exploring Sharing Suggestions to Enhance Family Connectedness. In *Proceedings of the 2008 ACM Conference on Computer Supported Cooperative Work* (San Diego, CA, USA) *(CSCW '08)*. Association for Computing Machinery, New York, NY, USA, 629–638. https://doi.org/10.1145/1460563.1460661

[16] Statistics Canada. 2021. Smartphone use and smartphone habits by gender and age group. https://doi.org/10.25318/2210011501-eng

[17] Tina Chan, Robert P. Gauthier, Ally Suarez, Nicholas F. Sia, and James R. Wallace. 2021. Merlynne: Motivating Peer-to-Peer Cognitive Behavioral Therapy with a Serious Game. *Proc. ACM Hum.-Comput. Interact.* 5, CHI PLAY, Article 250 (oct 2021), 23 pages. https://doi.org/10.1145/3474677

[18] Scott Conard. 2019. Best practices in digital health literacy. *International Journal of Cardiology* 292 (2019), 277–279. https://doi.org/10.1016/j.ijcard.2019.05.070

[19] Michael R Cope, Carol Ward, Jorden E Jackson, Kayci A Muirbrook, and Alex Nicholas Andre. 2020. Taking another look at the sense of community index: Six confirmatory factor analyses. *Journal of community psychology* 48, 5 (2020), 1410–1423.

[20] Michael Correll. 2019. Ethical Dimensions of Visualization Research. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300418

[21] Audrey Desjardins, Ron Wakkary, and William Odom. 2015. Investigating genres and perspectives in HCI research on the home. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. 3073–3082.

[22] Graham Dove, Nicolai Brodersen Hansen, and Kim Halskov. 2016. An Argument For Design Space Reflection. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction* (Gothenburg, Sweden) *(NordiCHI '16)*. Association for Computing Machinery, New York, NY, USA, Article 17, 10 pages. https://doi.org/10.1145/2971485.2971528

[23] Pouya Eghbali, Kaisa Väänänen, and Tero Jokela. 2019. Social Acceptability of Virtual Reality in Public Spaces: Experiential Factors and Design Recommendations. In *Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia* (Pisa, Italy) *(MUM '19)*. Association for Computing Machinery, New York, NY, USA, Article 28, 11 pages. https://doi.org/10.1145/3365610.3365647

[24] Abdallah El Ali, Ekaterina R. Stepanova, Shalvi Palande, Angelika Mader, Pablo Cesar, and Kaspar Jansen. 2023. BreatheWithMe: Exploring Visual and Vibrotactile Displays for Social Breath Awareness during Colocated, Collaborative Tasks. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 58, 8 pages. https://doi.org/10.1145/3544549.3585589

[25] Barrett Ens, Benjamin Bach, Maxime Cordeil, Ulrich Engelke, Marcos Serrano, Wesley Willett, Arnaud Prouzeau, Christoph Anthes, Wolfgang Büschel, Cody Dunne, et al. 2021. Grand challenges in immersive analytics. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–17.

[26] Barrett Ens, Benjamin Bach, Maxime Cordeil, Ulrich Engelke, Marcos Serrano, Wesley Willett, Arnaud Prouzeau, Christoph Anthes, Wolfgang Büschel, Cody Dunne, Tim Dwyer, Jens Grubert, Jason H. Haga, Nurit Kirshenbaum, Dylan Kobayashi, Tica Lin, Monsurat Olaosebikan, Fabian Pointecker, David Saffo, Nazmus Saquib, Dieter Schmalstieg, Danielle Albers Szafir, Matt Whitlock, and Yalong Yang. 2021. Grand Challenges in Immersive Analytics. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 459, 17 pages. https://doi.org/10.1145/3411764.3446866

[27] Jeremy Flaherty, Rodney R. Zwick, and Heather A. Bouchey. 2014. REVISITING THE SENSE OF COMMUNITY INDEX: A CONFIRMATORY FACTOR ANALYSIS AND INVARIANCE TEST. *Journal of Community Psychology* 42, 8 (2014), 947–963. https://doi.org/10.1002/jcop.21664 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/jcop.21664

[28] Asbjørn Følstad, Petter Bae Brandtzaeg, Tom Feltwell, Effie L-C. Law, Manfred Tscheligi, and Ewa A. Luger. 2018. SIG: Chatbots for Social Good. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA '18)*. Association for Computing Machinery, New York, NY, USA, 1–4. https://doi.org/10.1145/3170427.3185372

[29] David M Frost and Ilan H Meyer. 2012. Measuring community connectedness among diverse sexual minority populations. *Journal of sex research* 49, 1 (2012), 36–49.

[30] David M Frost, Ilan H Meyer, Andy Lin, Bianca DM Wilson, Marguerita Lightfoot, Stephen T Russell, and Phillip L Hammack. 2022. Social change and the health of sexual minority individuals: do the effects of minority stress and community connectedness vary by age cohort? *Archives of sexual behavior* 51, 4 (2022), 2299–2316.

[31] Verena Fuchsberger, Janne Mascha Beuthel, Dorothé Smit, Philippe Bentegeac, Manfred Tscheligi, Marije Nouwen, Bieke Zaman, and Tanja Döring. 2020. Designing for Tangible (Un-)Connectedness. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 409–412. https://doi.org/10.1145/3393914.3395916

[32] Robert P Gauthier, Mary Jean Costello, and James R Wallace. 2022. "I Will Not Drink With You Today": A Topic-Guided Thematic Analysis of Addiction Recovery on Reddit. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 20, 17 pages. https://doi.org/10.1145/3491102.3502076

[33] William W. Gaver, John Bowers, Andrew Boucher, Hans Gellerson, Sarah Pennington, Albrecht Schmidt, Anthony Steed, Nicholas Villars, and Brendan Walker. 2004. The Drift Table: Designing for Ludic Engagement. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems* (Vienna, Austria) *(CHI EA '04)*. Association for Computing Machinery, New York, NY, USA, 885–900. https://doi.org/10.1145/985921.985947

[34] Saul Greenberg and Bill Buxton. 2008. Usability Evaluation Considered Harmful (Some of the Time). In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy) *(CHI '08)*. Association for Computing Machinery, New York, NY, USA, 111–120. https://doi.org/10.1145/1357054.1357074

[35] Christina Harrington, Aqueasha Martin-Hammond, and Kirsten E Bray. 2022. Examining Identity as a Variable of Health Technology Research for Older Adults: A Systematic Review. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 265, 24 pages. https://doi.org/10.1145/3491102.3517621

[36] Kristina Höök and Jonas Löwgren. 2012. Strong Concepts: Intermediate-Level Knowledge in Interaction Design Research. *ACM Trans. Comput.-Hum. Interact.* 19, 3, Article 23 (oct 2012), 18 pages. https://doi.org/10.1145/2362364.2362371

[37] Long-Jing Hsu, Janice K Bays, Katherine M. Tsui, and Selma Sabanovic. 2023. Co-designing Social Robots with People Living with Dementia: Fostering Identity, Connectedness, Security, and Autonomy. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference* (, Pittsburgh, PA, USA,) *(DIS '23)*. Association for Computing Machinery, New York, NY, USA, 2672–2688. https://doi.org/10.1145/3563657.3595987

[38] Keiko Katsuragawa, Krzysztof Pietroszek, James R. Wallace, and Edward Lank. 2016. Watchpoint: Freehand Pointing with a Smartwatch in a Ubiquitous Display Environment. In *Proceedings of the International Working Conference on Advanced Visual Interfaces* (Bari, Italy) *(AVI '16)*. Association for Computing Machinery, New York, NY, USA, 128–135. https://doi.org/10.1145/2909132.2909263

[39] Ichiro Kawachi and Lisa F Berkman. 2001. Social ties and mental health. *Journal of Urban health* 78, 3 (2001), 458–467.

[40] Jesper Kjeldskov and Jeni Paay. 2012. A longitudinal review of Mobile HCI research methods. In *Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services*. 69–78.

[41] Predrag Klasnja, Sunny Consolvo, and Wanda Pratt. 2011. How to Evaluate Technologies for Health Behavior Change in HCI Research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 3063–3072. https://doi.org/10.1145/1978942.1979396

[42] M. Kraus, N. Weiler, D. Oelke, J. Kehrer, D. A. Keim, and J. Fuchs. 2020. The Impact of Immersion on Cluster Identification Tasks. *IEEE Transactions on Visualization and Computer Graphics* 26, 1 (2020), 525–535. https://doi.org/10.1109/TVCG.2019.2934395

[43] Ricardo Langner, Marc Satkowski, Wolfgang Büschel, and Raimund Dachselt. 2021. MARVIS: Combining Mobile Devices and Augmented Reality for Visual Data Analysis. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 468, 17 pages. https://doi.org/10.1145/3411764.3445593

[44] Emily G. Lattie, Rachel Kornfield, Kathryn E. Ringland, Renwen Zhang, Nathan Winquist, and Madhu Reddy. 2020. Designing Mental Health Technologies That Support the Social Ecosystem of College Students. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3313831.3376362

[45] Bongshin Lee, Raimund Dachselt, Petra Isenberg, and Eun Kyoung Choe. 2021. *Mobile Data Visualization*. CRC Press, New York, USA.

[46] Sebastian Linxen, Christian Sturm, Florian Brühlmann, Vincent Cassau, Klaus Opwis, and Katharina Reinecke. 2021. How WEIRD is CHI?. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 143, 14 pages. https://doi.org/10.1145/3411764.3445488

[47] María Jesús Lobo, Christophe Hurter, and Pourang Irani. 2020. Flex-ER: A Platform to Evaluate Interaction Techniques for Immersive Visualizations. *Proc. ACM Hum.-Comput. Interact.* 4, ISS, Article 195 (nov 2020), 20 pages. https://doi.org/10.1145/3427323

[48] D Adam Long and Douglas D Perkins. 2003. Confirmatory factor analysis of the sense of community index and development of a brief SCI. *Journal of community psychology* 31, 3 (2003), 279–296.

[49] Aaron Lyon, Sean A. Munson, Madhu Reddy, Stephen M. Schueller, Elena Agapie, Svetlana Yarosh, Alex Dopp, Ulrica von Thiele Schwarz, Gavin Doherty, Andrea K Graham, Kaylee Payne Kruzan, and Rachel Kornfield. 2023. Bridging HCI and Implementation Science for Innovation Adoption and Public Health Impact. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 336, 7 pages. https://doi.org/10.1145/3544549.3574132

[50] Cayley MacArthur, Arielle Grinberg, Daniel Harley, and Mark Hancock. 2021. You're Making Me Sick: A Systematic Review of How Virtual Reality Research Considers Gender & Cybersickness. In *Proceedings of the 2021 CHI Conference*

on Human Factors in Computing Systems (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 401, 15 pages. https://doi.org/10.1145/3411764.3445701

[51] Kim Marriott, Falk Schreiber, Tim Dwyer, Karsten Klein, Nathalie Henry Riche, Takayuki Itoh, Wolfgang Stuerzlinger, and Bruce H Thomas. 2018. *Immersive analytics*. Vol. 11190. Springer, New York, USA.

[52] Debra Mashek, Lisa W Cannaday, and June P Tangney. 2007. Inclusion of community in self scale: A single-item pictorial measure of community connectedness. *Journal of Community Psychology* 35, 2 (2007), 257–275.

[53] Samantha L Matlin, Sherry Davis Molock, and Jacob Kraemer Tebes. 2011. Suicidality and depression among african american adolescents: the role of family and peer support and community connectedness. *American journal of orthopsychiatry* 81, 1 (2011), 108.

[54] Katharine F. McBride, Christine Franks, Vicki Wade, Veronica King, Janice Rigney, Nyunmiti Burton, Anna Dowling, Natasha J. Howard, Catherine Paquet, Susan Hillier, Stephen J. Nicholls, and Alex Brown. 2021. Good Heart: Telling Stories of Cardiovascular Protective and Risk Factors for Aboriginal Women. *Heart, Lung and Circulation* 30, 1 (2021), 69–77. https://doi.org/10.1016/j.hlc.2020.09.931 Women's Heart Health.

[55] Gloria Mittmann, Adam Barnard, Ina Krammer, Diogo Martins, and João Dias. 2022. LINA - A Social Augmented Reality Game around Mental Health, Supporting Real-World Connection and Sense of Belonging for Early Adolescents. *Proc. ACM Hum.-Comput. Interact.* 6, CHI PLAY, Article 242 (oct 2022), 21 pages. https://doi.org/10.1145/3549505

[56] Luiz Morais, Yvonne Jansen, Nazareno Andrade, and Pierre Dragicevic. 2022. Showing Data About People: A Design Space of Anthropographics. *IEEE Transactions on Visualization and Computer Graphics* 28, 3 (2022), 1661–1679. https://doi.org/10.1109/TVCG.2020.3023013

[57] Tamara Munzner. 2014. *Visualization analysis and design*. CRC press.

[58] Akshay Murari, Elias Mahfoud, Weichao Wang, and Aidong Lu. 2021. Cross-Platform Immersive Visualization and Navigation with Augmented Reality. In *The 14th International Symposium on Visual Information Communication and Interaction* (Potsdam, Germany) *(VINCI 2021)*. Association for Computing Machinery, New York, NY, USA, Article 12, 9 pages. https://doi.org/10.1145/3481549.3481564

[59] Bonnie Nardi and Justin Harris. 2006. Strangers and Friends: Collaborative Play in World of Warcraft. In *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work* (Banff, Alberta, Canada) *(CSCW '06)*. Association for Computing Machinery, New York, NY, USA, 149–158. https://doi.org/10.1145/1180875.1180898

[60] Shuo Niu, Ava Bartolome, Cat Mai, and Nguyen Binh Ha. 2021. #StayHome #WithMe: How Do YouTubers Help with COVID-19 Loneliness?. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 338, 15 pages. https://doi.org/10.1145/3411764.3445397

[61] Barbara Leonhard Norton. 2006. *Does Community Connectedness Matter?: Exploring the Association Between Protective Social Factors and Preventive Health Behaviors in a Culturally Diverse, Environmentally Stressed Context*. Ph. D. Dissertation. University of Oklahoma.

[62] William Odom, Ron Wakkary, Youn-kyung Lim, Audrey Desjardins, Bart Hengeveld, and Richard Banks. 2016. From Research Prototype to Research Product. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 2549–2561. https://doi.org/10.1145/2858036.2858447

[63] National Institutes of Health. 2021. Clear & simple. https://www.nih.gov/institutes-nih/nih-office-director/office-communications-public-liaison/clear-communication/clear-simple

[64] Heather Palis, Kirsten Marchand, and Eugenia Oviedo-Joekes. 2020. The relationship between sense of community belonging and self-rated mental health among Canadians with mental or substance use disorders. *Journal of Mental Health* 29, 2 (2020), 168–175.

[65] Sachin R Pendse, Daniel Nkemelu, Nicola J Bidwell, Sushrut Jadhav, Soumitra Pathare, Munmun De Choudhury, and Neha Kumar. 2022. From Treatment to Healing:Envisioning a Decolonial Digital Mental Health. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 548, 23 pages. https://doi.org/10.1145/3491102.3501982

[66] Trevor Perrier, Nicola Dell, Brian DeRenzi, Richard Anderson, John Kinuthia, Jennifer Unger, and Grace John-Stewart. 2015. Engaging Pregnant Women in Kenya with a Hybrid Computer-Human SMS Communication System. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 1429–1438. https://doi.org/10.1145/2702123.2702124

[67] N. Andrew Peterson, Paul W. Speer, and David W. McMillan. 2008. Validation of A brief sense of community scale: Confirmation of the principal theory of sense of community. *Journal of Community Psychology* 36, 1 (2008), 61–73. https://doi.org/10.1002/jcop.20217 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/jcop.20217

[68] James Pierce. 2014. On the Presentation and Production of Design Research Artifacts in HCI. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (Vancouver, BC, Canada) *(DIS '14)*. Association for Computing Machinery, New York, NY, USA, 735–744. https://doi.org/10.1145/2598510.2598525

[69] Krzysztof Pietroszek, James R. Wallace, and Edward Lank. 2015. Tiltcasting: 3D Interaction on Large Displays Using a Mobile Device. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology* (Charlotte, NC, USA) *(UIST '15)*. Association for Computing Machinery, New York, NY, USA, 57–62. https://doi.org/10.1145/2807442.2807471

[70] Shirley Porter. 2018. A Descriptive Study of Post-Secondary Student Mental Health Crises. *College Quarterly* 21, 3 (2018), n3.

[71] Arnaud Prouzeau, Maxime Cordeil, Clement Robin, Barrett Ens, Bruce H. Thomas, and Tim Dwyer. 2019. Scaptics and Highlight-Planes: Immersive Interaction Techniques for Finding Occluded Features in 3D Scatterplots. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3290605.3300555

[72] Patrick Reipschläger, Frederik Brudy, Raimund Dachselt, Justin Matejka, George Fitzmaurice, and Fraser Anderson. 2022. AvatAR: An Immersive Analysis Environment for Human Motion Data Combining Interactive 3D Avatars and Trajectories. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 23, 15 pages. https://doi.org/10.1145/3491102.3517676

[73] Alexandra M Robinson, Theresa M Jubenville, Katerina Renny, and Sharon L Cairns. 2016. Academic and mental health needs of students on a Canadian campus. *Canadian Journal of Counselling and Psychotherapy* 50, 2 (2016), 108–123.

[74] John Rooksby, Alistair Morrison, and Dave Murray-Rust. 2019. Student Perspectives on Digital Phenotyping: The Acceptability of Using Smartphone Data to Assess Mental Health. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3290605.3300655

[75] Jim Rowan and Elizabeth D. Mynatt. 2005. Digital Family Portrait Field Trial: Support for Aging in Place. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Portland, Oregon, USA) *(CHI '05)*. Association for Computing Machinery, New York, NY, USA, 521–530. https://doi.org/10.1145/1054972.1055044

[76] Anastasia Ruvimova, Junhyeok Kim, Thomas Fritz, Mark Hancock, and David C. Shepherd. 2020. "Transport Me Away": Fostering Flow in Open Offices through Virtual Reality. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376724

[77] Robert J. Sampson, Stephen W. Raudenbush, and Felton Earls. 1997. Neighborhoods and Violent Crime: A Multilevel Study of Collective Efficacy. *Science* 277, 5328 (1997), 918–9.

[78] Marc Satkowski and Raimund Dachselt. 2021. Investigating the Impact of Real-World Environments on the Perception of 2D Visualizations in Augmented Reality. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 522, 15 pages. https://doi.org/10.1145/3411764.3445330

[79] Marc Satkowski, Weizhou Luo, and Raimund Dachselt. 2021. Towards In-situ Authoring of AR Visualizations with Mobile Devices. In *2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*. IEEE, Bari, Italy, 324–325. https://doi.org/10.1109/ISMAR-Adjunct54149.2021.00073

[80] Renata Schiavo. 2013. *Health communication: From theory to practice*. Vol. 217. John Wiley & Sons, New York, NY, USA.

[81] Isabel Schwaninger, Christopher Frauenberger, and Geraldine Fitzpatrick. 2020. Unpacking Forms of Relatedness around Older People and Telecare. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 163–169. https://doi.org/10.1145/3393914.3395867

[82] Velvet Spors and Imo Kaufman. 2021. Respawn, Reload, Relate: Exploring the Self-Care Possibilities for Mental Health in Games through a Humanistic Lens. *Proc. ACM Hum.-Comput. Interact.* 5, CHI PLAY, Article 263 (oct 2021), 31 pages. https://doi.org/10.1145/3474690

[83] Philipp Sykownik, Divine Maloney, Guo Freeman, and Maic Masuch. 2022. Something Personal from the Metaverse: Goals, Topics, and Contextual Factors of Self-Disclosure in Commercial Social VR. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 632, 17 pages. https://doi.org/10.1145/3491102.3502008

[84] Chia-Chi Teng, Nathan Jensen, Timothy Smith, Talon Forbush, Kyle Fletcher, and Michael Hoover. 2018. Interactive Augmented Live Virtual Reality Streaming: A Health Care Application. In *Proceedings of the 2nd International Conference on*

Medical and Health Informatics (Tsukuba, Japan) *(ICMHI '18)*. Association for Computing Machinery, New York, NY, USA, 143–147. https://doi.org/10.1145/3239438.3239456

[85] Thomas Visser, Pavan Dadlani, Daan van Bel, and Svetlana Yarosh. 2010. Designing and Evaluating Affective Aspects of Sociable Media to Support Social Connectedness. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems* (Atlanta, Georgia, USA) *(CHI EA '10)*. Association for Computing Machinery, New York, NY, USA, 4437–4440. https://doi.org/10.1145/1753846.1754168

[86] Qiaosi Wang, Shan Jing, and Ashok K. Goel. 2022. Co-Designing AI Agents to Support Social Connectedness Among Online Learners: Functionalities, Social Characteristics, and Ethical Challenges. In *Proceedings of the 2022 ACM Designing Interactive Systems Conference* (, Virtual Event, Australia,) *(DIS '22)*. Association for Computing Machinery, New York, NY, USA, 541–556. https://doi.org/10.1145/3532106.3533534

[87] Yun Wang, Adrien Segal, Roberta Klatzky, Daniel F. Keefe, Petra Isenberg, Jörn Hurtienne, Eva Hornecker, Tim Dwyer, and Stephen Barrass. 2019. An Emotional Response to the Value of Visualization. *IEEE Computer Graphics and Applications* 39, 5 (2019), 8–17. https://doi.org/10.1109/MCG.2019.2923483

[88] Yuna Watanabe, Xi Laura Cang, Rúbia Reis Guerra, Devyani Mclaren, Preeti Vyas, Jun Rekimoto, and Karon E Maclean. 2023. Demonstrating Virtual Teamwork with Synchrobots: A Robot-Mediated Approach to Improving Connectedness. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 441, 4 pages. https://doi.org/10.1145/3544549.3583896

[89] Andrew D. Wilson and Hrvoje Benko. 2017. Holograms without Headsets: Projected Augmented Reality with the RoomAlive Toolkit. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI EA '17)*. Association for Computing Machinery, New York, NY, USA, 425–428. https://doi.org/10.1145/3027063.3050433

[90] John Zimmerman and Jodi Forlizzi. 2014. Research through design in HCI. In *Ways of Knowing in HCI*. Springer, New York, USA, 167–189.

[91] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. Association for Computing Machinery, New York, USA, 493–502.

[92] Michael Zonneveld, Ann-Helen Patomella, Eric Asaba, and Susanne Guidetti. 2020. The use of information and communication technology in healthcare to improve participation in everyday life: a scoping review. *Disability and Rehabilitation* 42, 23 (2020), 3416–3423. https://doi.org/10.1080/09638288.2019.1592246 arXiv:https://doi.org/10.1080/09638288.2019.1592246 PMID: 30966833.