Immersive Analysis of Health-Related Data with Mixed Reality Interfaces: Potentials and Open Question

Jens Müller
University of Konstanz
78464 Konstanz
jens.mueller@uni-konstanz.de

Simon Butscher
University of Konstanz
78464 Konstanz
simon.butscher@uni-konstanz.de

Harald Reiterer
University of Konstanz
78464 Konstanz
harald.reiterer@uni-konstanz.de

ISS '16 Companion, November 06-09, 2016, Niagara Falls, ON, Canada
ACM 978-1-4503-4530-9/16/11.
http://dx.doi.org/10.1145/3009939.3009951

Abstract
In this paper we propose Mixed Reality (MR) interfaces as tools for the analysis and exploration of health-related data. Reported findings originate from the research project "SMARTACT" in which several intervention studies are conducted to investigate how participants' long-term health behavior can be improved. We conducted a focus group to identify limitations of current data analysis technologies and practices, possible uses of MR interfaces and associated open questions to leverage their potentials in the given domain.

Author Keywords
Mixed Reality; immersive data analysis, mobile interventions; health-related data.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

Introduction
Mixed Reality (MR) is defined as the "merging of real and virtual worlds" on a display [17]. Thereby MR displays create the illusion as if virtual objects were situated in the same physical space [18] (Figure 1).

Figure 1. Collaborative Mixed Reality (MR) experience with MR tablets [18]. Two collaborators can explore digital information which is integrated in their physical environment and represented as virtual objects.

HCI research has demonstrated MR interfaces as being beneficial for several application domains, such as architecture [15], computer-aided instruction [9], education [1,4], medical visualizations [2], and data analysis [7], as well as tools for computer-supported collaborative work (CSCW) (e.g., [3,5,12,20]).

In this paper we suggest MR displays as tools to analyze and explore health-related data from mobile interventions. We first present the application domain and then report on our findings from a focus group that we conducted to better understand how MR displays can enhance analytical tasks within the given domain. We then illustrate potential scenarios both for individual and collaborative analysis of health-related data. In addition, we discuss open questions that research needs to address in order to advance the potentials of MR interfaces as tools for immersive data analysis. At the workshop, we would like discuss about the benefits and tradeoffs of MR technologies for immersive data analysis.

Description of the Research Project

This work is part of the SMARTACT [13,14] project. The interdisciplinary project consists of psychologists, sport scientists, computer scientists, and economists and pursues the goal of improving people's long-term health behavior via mobile devices. For this, several contexts, which are essential for subjective well-being (e.g., family environment and work space), are taken into account. We developed a toolbox which enables mobile intervention studies to investigate eating behavior, psychological aspects (e.g., eating motives and emotional states), context-related aspects such as subjective stress levels in different social contexts (e.g., family, workplace), and physical activity. These data are currently gathered via questionnaires, photo taking/food journaling during the intervention studies by the participants' smartphones and additional physical activity trackers.

For effective health behavior change, users not only need to be able to track their behavior, they also need to be provided with visual presentations of the collected information for self-monitoring [6,8]. The effectiveness of feedback visualizations, however, has not been widely investigated [10].

But analysis of collected data is not only relevant for end users: The ability to interpret end users' data is also crucial for researchers and medical practitioners. Analysis of data can become particularly challenging for researchers as they typically have to analyze large amounts of data resulting from multiple participants.

Focus Group: Current Limitations, Opportunities & Challenges

To identify situations in which MR interfaces can enhance current analysis practices in the given domain, we conducted a focus group (2h) with 11 domain experts (health psychologists, biological psychologists, and interaction designers) from the project. First, current scenarios, in which data needs to be visualized and interpreted, were identified (approx. 45min). In addition, associated limitations were discussed. Then, interaction designers provided an MR technology demonstration of the Oculus Rift [19], which was enhanced with see-through functionality, and the Google Project Tango tablets [11] (approx. 30min). Afterwards, both possible use cases for MR interfaces as tools to enhance visual analysis and open issues were discussed (approx. 45min).

We structured our results according to the identified situations in which visual analysis of health-related data was considered relevant, henceforth referred to as "perspectives."

1) App user perspective

This perspective refers to the end users and the visual feedback they are provided for self-monitoring.

Current limitations: Researchers considered the display sizes of users' smartphones to be the main limitation with respect to the large amounts of time-based and multidimensional data to be visualized. They particularly missed possibilities to effectively visualize behavioral data over time. This makes self-monitoring rather problematic as the user may not be able to identify trends in their behavior as relevant data may be off-screen. Furthermore, limited screen sizes allow visualizing only a limited number of dimensions (e.g., eating motives and emotional states) in a comprehensible manner.

Opportunities: There was universal consensus that MR technologies can help end users to better understand their tracked data because these MR technologies can utilize the users' physical environment to explore large amounts of data. Thereby users could place the time dimension on a walkable time line. Data from additional variables (e.g., type of food and motivation) could then be visualized as data points on a vertical layer at the associated point in time (e.g., through virtual 3D objects). Furthermore, focus group members saw great potential in the egocentric navigation which MR interfaces provide, because it allows users to explore their data from different angles, e.g., through optical bearing.

Open questions: While there was universal consensus about the potentials of MR interfaces as tools for visual data analysis, there was no clear answer on how to exactly lay out the data and whether it is reasonable to refer to typical 2D visualization such as bar charts or pie charts. In addition, well established techniques to change the level of detail, such as zooming, may not work comparably well in a 3D space. Another unanswered question was that of data manipulation: in 2D interfaces users can typically customize their data view (e.g., filtering, mapping particular dimension on a scatter plot, changing axes). Thus, research needs to investigate how current practices of data manipulation and view customization can be made possible for these novel interface types in an intuitive way.

2) Researcher perspective

This perspective refers to situations where data that is gathered from one or more end users is analyzed by researchers or a medical practitioner. Researchers typically have to deal with large amounts of data from various participants to identify both intra- and interindividual behavioral differences and patterns. Researchers stated two main goals of visual analysis: 1) identification of so-called behavior signatures of individuals where behavior signatures are defined as situation-dependent factors (e.g., time, duration, and frequency of psychological variables) and 2) visualization of relationships between behavior signatures and related outcomes such as body mass index and blood levels. Currently they use tools like MS Excel [16] for data preparation and Tableau [21] for visual data analysis.

Current limitations: For data analysis they mentioned the restriction that synchronous collaboration is not sufficiently supported but highly desirable, in particular for explorative tasks such as the identification of behavioral patterns and signatures. In addition, they considered current desktop-based systems too limited in terms of the maximum number of dimensions that can be displayed.

Opportunities: The domain experts saw great potentials in MR technologies to explore and analyze the large amounts of data from intervention studies. They stated two reasons: First, similar to the end user perspective, the utilization of the physical environment would allow them to better visualize and interpret significantly more data at the same time, and secondly, they considered the potential of co-located and remote collaboration particularly important. Interesting patterns and outliers could then be identified collaboratively and could be discussed immediately. In addition, the provided egocentric navigation would allow them to take different perspectives on the data. Furthermore, they hypothesized that MR interfaces would allow them to cluster data by positioning relevant data points (i.e., from participants who share a specific behavioral pattern) to a distinct place in their physical environment. As a last point they mentioned that the possibility for collaboration via MR interfaces might also be beneficial in a clinical context: Within their consultation-hours, clinical practitioners might be able to discuss their patients' data both face-to-face but also via remote collaboration.

Open questions: Similar to the issues that have been raised in the app users' perspective, domain experts were uncertain on how to exactly visualize the data (e.g., hierarchies of interpersonal data), and how to practically manipulate the data in order to make the mentioned ideas possible (e.g., how to cluster, grab, and move specific data points). In addition, they considered remote collaboration with MR interfaces particularly challenging for analytical tasks: collaborative analysis often requires the collaborators to guide each other's attention to specific points of interest, which can become problematic when collaborators do not have a shared visual context.

Conclusion

In this paper we proposed MR interfaces as tools for immersive exploration and analysis of health-related data. We conducted a focus group to identify limitations of current technologies and practices, possible perspective of MR interfaces and associated open questions to advance their potentials in the given domain.

References

1. Dünser. Andreas and Eva Hornecker. 2007. Lessons from an AR Book Study. *Proceedings of the 1st International Conference on Tangible and Embedded Interaction (TEI '07)*, 179–182.
2. Michael Bajura, Henry Fuchs, and Ryutarou Ohbuchi. 1992. Merging Virtual Objects with the Real World: Seeing Ultrasound Imagery Within the Patient. *Proceedings of the 19th Annual Conference on Computer Graphics and Interactive Techniques*, 203–210.
3. Steve Benford, Chris Greenhalgh, Gail Reynard, Chris Brown, and Boriana Koleva. 1998. Understanding and Constructing Shared Spaces with Mixed-Reality Boundaries. *ACM Transactions on Computer-Human Interaction* 5, 3: 185–223. http://doi.org/10.1145/292834.292836
4. Mark Billinghurst, Hirokazu Kato, and Ivan Poupyrev. 2001. The MagicBook: A transitional AR interface. *Computers and Graphics (Pergamon)*, 745–753. http://doi.org/10.1016/S0097-8493(01)00117-0
5. Mark Billinghurst and Hirokazu Kato. 1999. Collaborative Mixed Reality. *Proc. of ISMR '99*, Springer, 261–284. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.107.682&rep=rep1&type=pdf
6. Maurizio Caon, Stefano Carrino, Federica Prinelli, et al. 2015. Towards an Engaging Mobile Food Record for Teenagers. In *New Trends in Image Analysis and Processing -- ICIAP 2015 Workshops: ICIAP 2015 International Workshops, BioFor, CTMR, RHEUMA, ISCA, MADiMa, SBMI, and QoEM, Genoa, Italy, September 7-8, 2015, Proceedings*, Vittorio Murino, Enrico Puppo, Diego Sona, Marco Cristani and Carlo Sansone (eds.). Springer International Publishing, Cham, 417–424. http://doi.org/10.1007/978-3-319-23222-5_51
7. Tom Chandler, Maxime Cordeil, Tobias Czauderna, et al. 2015. Immersive Analytics. *2015 Big Data Visual Analytics (BDVA)*: 1–8. http://doi.org/10.1109/BDVA.2015.7314296
8. Sunny Consolvo, Predrag Klasnja, David W. McDonald, and James A. Landay. 2012. Designing for Healthy Lifestyles: Design Considerations for Mobile Technologies to Encourage Consumer Health and Wellness. *Foundations and Trends® in Human–Computer Interaction* 6, 3–4: 167–315. http://doi.org/10.1561/1100000040
9. Steven Feiner, Blair Macintyre, and Dorée Seligmann. 1993. Knowledge-based Augmented Reality. *Commun. ACM* 36: 53–62.
10. Caroline Free, Gemma Phillips, Leandro Galli, et al. 2013. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. *PLoS Medicine* 10, 1: e1001362. http://doi.org/10.1371/journal.pmed.1001362
11. Google Inc. 2016. Project Tango. Retrieved from https://get.google.com/tango/
12. Raphael Grasset, Philip Lamb, and Mark Billinghurst. 2005. Evaluation of Mixed-Space Collaboration. *Proc. of ISMAR '05*, 90–99.
13. HCI group University of Konstanz. 2015. SMARTACT / SMARTMOBILITY. Retrieved from http://hci.uni-konstanz.de/smartact
14. University of Konstanz. 2015. SMARTACT. Retrieved from https://www.uni-konstanz.de/smartact/
15. Gun A. Lee, Andreas Dunser, Seungwon Kim, and Mark Billinghurst. 2012. CityViewAR: A mobile outdoor AR application for city visualization. *2013 IEEE International Symposium on Mixed and Augmented Reality - Arts, Media, and Humanities (ISMAR-AMH)*: 57–64.
16. Microsoft. 2016. Microsoft Excel. Retrieved from http://office.microsoft.com/en-us/excel

17. Paul Milgram and Fumio Kishino. 1994. Taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, 1321–1329. http://doi.org/10.1.1.102.4646

18. Jens Müller, Roman Rädle, and Harald Reiterer. 2016. Virtual Objects As Spatial Cues in Collaborative Mixed Reality Environments: How They Shape Communication Behavior and User Task Load. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 1245–1249. http://doi.org/10.1145/2858036.2858043

19. LLC Oculus VR. 2016. Oculus Rift. Retrieved from https://www3.oculus.com/en-us/rift/

20. Dieter Schmalstieg, Anton Fuhrmann, Zsolt Szalavari, and Michael Gervautz. 1996. "Studierstube" - An Environment for Collaboration in Augmented Reality". *Proc of CVE (Extended abstract)*, 19–20. http://doi.org/10.1007/BF01409796

21. TABLEAU SOFTWARE. Tableau. Retrieved from http://www.tableau.com/