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Designing for Health, Engagement and Social-Interaction: A Multimodal and AR-based Sport System to facilitate digital Connectedness over Distances

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Abstract. This work presents a prototype for a multimodal and augmented-reality (AR) based system designed to facilitate individual and social activities, promote health and well-being and support participation for various people. A practice-based design and research approach was used to explore requirements, to conceptualize, design and develop AR-based activities for a multimodal interaction. We have interviewed members from seven different sports associations and conducted design workshops to understand how to design AR-applications to promote an active lifestyle and at the same time to build a bridge for new sustainable societies and active communities. The prototype and approach presented here will serve to discuss and reflect future research activities, methodological concepts, and experiences in the field of HCI, sports, and AR.

Introduction

Physical activity (PA) has multiplicative health, social and economic benefits, can create connections in many ways, and plays an essential role in the everyday life of many people: physical activities have a positive impact on physical and mental health and make a valuable contribution to social participation and individual mobility (Cooper et al., 2015; Guthold et al., 2018). Therefore, promoting PA, social interaction and participation is

directly in line with Sustainable Development Goal from the United Nations, which is focusing on *ensuring healthy lives and promote well-being for all at all ages* (Aal et al., 2016; United Nations, 2022). There are multiple direct and indirect pathways to promote PA through, e.g., walking, cycling, sport, active recreation, and play support. However, for the last 20 years, there has been a concerning worldwide trend in insufficient PA (Cooper et al., 2015; Guthold et al., 2018; Hallal et al., 2012) due to an increasingly sedentary lifestyle (Hallal et al., 2012). This favors a visible increase in overweight and obesity in the populations of industrialized nations (Reilly et al., 2018) and a related increase in chronic diseases such as diabetes type 2 or various cardiovascular diseases (Chen et al., 2012). The use of health-related information and communication technology (ICT) such as exergames (Smeddinck et al., 2015; Unbehaun et al., 2019, 2020; Unbehaun, Vaziri, Aal, Li, et al., 2018; Unbehaun, Vaziri, Aal, Wieching, et al., 2018), health applications and wearables (Vaziri, 2018), as well as digital games and training programs (Brown et al., 2022; Vaziri et al., 2017) in different domains, shown to improve activity levels and offer valuable potentials. Recently, virtual and augmented realities (VR and AR) are becoming increasingly visible in the field of health-related ICT and Human-Computer-Interaction (HCI) (Janßen et al., 2021; Janßen & Prilla, 2022; Raß et al., 2023; Taugerbeck et al., 2019; Unbehaun et al., 2019, 2021; Yoo et al., 2020). Our work presents an AR-based system to foster physical activity, facilitate social interaction, and create an innovative interface to access and promote health and active participation across all ages and abilities. In this work, we identified individual and organizational requirements, designed and developed an AR-based System aiming to adapt sports activities and combine them with AR approaches and multi-user applications to create new multimodal scenarios in individual and social outdoor interactions. The system was contextualized, designed, and developed with actors (athletes and clubs) and additional stakeholders (associations and multipliers). By exploring system requirements and implementing the system in sport-communities, the goal is to enable an innovative and active social lifestyle for various social groups and establish a socio-technical "*innovation space*" (Edwards-Schachter et al., 2012), which transfers innovations from academia and various industries into individual and institutional practices. Thus, the project explored how AR-based exercises and activities need to be designed to enable participation across distances as well as how they may foster participation, communication and social interaction across generations. The presented results and prototype will therefore serve as a platform to discuss and reflect upcoming research activities, methodological concepts, and experiences in the field of HCI, CSCW, and augmented reality.

Related Work

Physical Activity and Interactive Technologies

A sedentary lifestyle, stress at work, and omnipresent availability of industrialized food – collateral consequences of today's civilization and economic growth – create new enormous challenges to the state of health of many people. PA decreases, whereas

obesity, diabetes, heart diseases and other related health problems increase almost worldwide (*Obesity and Overweight*, o. J.). One of the major approaches for developing an active population and tackling common lifestyle diseases is implementing PA in people's everyday lives. The WHO defines PA as "any bodily movement produced by skeletal muscles that require energy expenditure. PA refers to all movement including during leisure time, for transport to get to and from places, or as part of a person's work" (*Physical Activity*, o. J.). Technologies have been used in the context of sports before for several purposes. Very acquainted are the traditional step counters, which use pedometers to detect daily step counts to assess and motivate PA behaviors (Tudor-Locke & Bassett, 2004). The 10,000 steps/day goal gained popularity with the media and in practice because it appears to be a reasonable goal to benefit health (Kang et al., 2009). With digital games being among the most popular leisure activities, the lack of PA, time spent outdoors, and possible social isolation of players are critically discussed (Wulf et al., 2004). However, the supposedly challenging games and technologies could also be used to work against this trend. Under the impression that people indicated a lack of enjoyment and preferred to do other things as barriers to PA, they offer considerable potential (Hoare et al., 2017). Recently, there have been many attempts to combine the motivational benefits of digital games with exercising, forming the new term "exergaming". Famous examples of the genre are games such as Dance Dance Revolution, Wii Fit, Kinect Sports, and Ring Fit Adventure. Researchers found that these interactive technologies could increase individuals' PA, self-efficacy, perceived social support, and enjoyment (Gao & Chen, 2014). They benefit several physiological parameters like energy expenditure, oxygen consumption and heart rate (Biddiss & Irwin, 2010; Peng et al., 2011). A well-known example of that genre is "Pokémon Go," which is exceptionally well received and cited by the media (Aal & Hauptmeier, 2019; *Pokémon Go Revenue and Usage Statistics (2021)*, 2017). Studies report that more than half of the active Pokémon Go users agreed that playing the game changed their walking habits, motivated them to go outdoors more often and made them walk to a destination (Merrimack College, School of Health Sciences, North Andover, MA, United States et al., 2020). The game also influences social behavior: Studies show that it can increase the time spent with family, which improves the bonding between parents and children (Sobel et al., 2017) or the number of friendships and leads to an intensification of friendships (Bonus et al., 2018).

Augmented Reality in HCI and Computer-Supported Collaborative Sports

Tieing in with new hybrid forms of exercise as seen in the genre of Exergames and the example of Pokémon Go, the field of Computer-supported collaborative sports tries to make use of new technologies by expanding sports experiences through Visual Augmentations (Aal & Hauptmeier, 2019; Unbehaun, Aal, Vaziri, Wieching, et al., 2018; Wulf et al., 2004). Those augmentations differ depending on the grade of virtuality. While there are Virtual Reality (VR) applications that completely replace the real world with virtual content, they are less common in sports contexts. Most augmented sports activities instead rely on either Augmented Reality (AR) which enhances the real world by providing additional input or (MR) which combines real and virtual elements to create

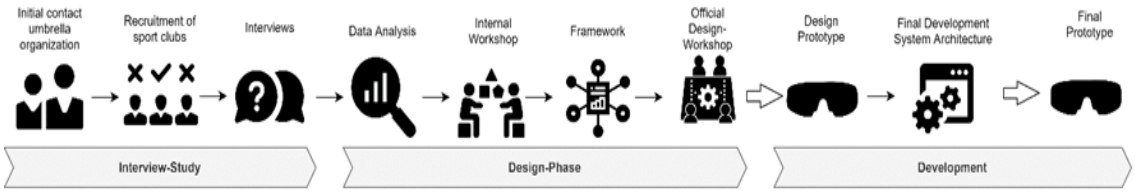
new immersive surroundings. These approaches lead to the user feeling like a part of their environment while still allowing them to see their actual movements and surroundings, rather than a completely virtual environment. Thus, AR and MR are more suitable for sports activities compared to VR technologies.

As Wulf et al. already argued in 2004, an augmented collaborative environment will lead to newly designed sports with entirely new game ideas (Wulf et al., 2004). In this vein, a newly emerging field focusing on recreational implications of MR technology is called "Superhuman Sports" (Eichhorn et al., 2020; Kunze et al., 2017). Superhuman Sports aims to create new sports experiences with enhanced human abilities through technological human augmentations (Kunze et al., 2017; Numan et al., 2019). Through Superhuman Sports, new sports such as "Hado" (Kunze et al., 2017), "Star Tag" (Numan et al., 2019)," League of Lasers" (Miedema et al., 2019), and "Catching the Drone" (Eichhorn et al., 2020) already emerged. Through AR, users of sports games, for example, can receive additional information in real-time and in real-life environments during gameplay and experience a range of innovative forms of activity through augmented reality and mixed reality technologies. AR glasses are already available in cycling, in areas such as movement training and rehabilitation (Anderson et al., 2013) in billiard and table tennis (Yeo et al., 2019), or sport climbing (Kajastila et al., 2016). Similarly, MR has been used to create complete environments for sports such as Basketball (Pai et al., 2018; Santoso, 2018). Future research interests refer to the opportunity to use AR/MR more commonly on a recreational level, such as making sports more challenging by designing visual obstacles (Yeo et al., 2019) or enabling the users to manually set their training as already the case in Augmented Climbing (Kajastila et al., 2016). The related research stresses the importance of motivational, social, and acceptance factors to support individual and social sports activity (Wulf et al., 2004). Similarly, social collaboration and competition prove to have a significant effect on motivation as well as acceptance and desirability of the device (Kunze et al., 2017).

Methods, Design, Data and Research Questions

By adapting a practice-based design approach, we aim to develop the system and the practical scenarios together with the target group (athletes, clubs, associations, and municipalities) to identify factors in the early stages of development that are relevant for the continuous use of the solution. The paper work seeks to address the following research questions: 1) Which specific practice-based factors are concerned in designing an AR-based system to foster physical activity, enable social participation and encourage their long-term use, and 2) to what extent can individual and social activities in the context of sports be supported by AR-based activities? Regarding data collection, we followed the Design Case Study Approach by Wulf (Ahmadi et al., 2018; Wulf et al., 2011) by applying different methods and participatory instruments from the fields of human-computer interaction (e.g., different levels of prototyping) and qualitative research (e.g. interviews, design workshops, participant observations). Our stakeholder network consists of sports clubs, and associations (see table 1) from different cities and rural areas.

To gain meaningful insights into the structure, daily routines, and organization of sports associations, we began with an empirical study regarding existing practices, organizational and social perspectives, individual and social needs, and the challenges confronting our target group in their everyday surroundings.
This involved semi-structured interviews with different sports associations. Right from the outset, the approach enabled an open collaboration amongst a variety of actors, reflecting their different perspectives, knowledge, interests, and expectations. In a second, iterative step, we conducted a design workshop together with managers, training group leaders and sport club members to discuss possible scenarios, use cases, technical restrictions, and barriers. Based on the initial interviews and internal workshops, the idea of a cooperative and competitive AR-Setup with various features evolved, which was then introduced to the sports associations and their members in the joint design workshop. All researchers participated in three sets of internal design workshops with different foci in which we developed the technical, organizational and social framework. The study



included overall 11 participants from sport associations with different backgrounds (see table 1 for an overview) and 9 members of the research and development team. The qualitative data consisted of audio recordings and field notes collected during the interviews and workshops. Our data analysis was performed using a Thematic Analysis (TA) approach (Braun & Clarke, 2006). This involves a series of established steps, including open coding of the data material, systematic revision of the coded segments, and identification of code families and their relationships in the search for themes. After the transcription of the interviews, the transcripts were reviewed and coded in an iterative process leading to the compilation of the data categories present in the collected data and to the elaboration of relationships between these categories. We identified the following principal themes during the coding sessions: individual adaptability; social aspects; and technical requirements. These overarching themes were derived from our original codes, which included terms such as motivation, interaction, participation, engagement, movement, etc. Coding differences were discussed and eliminated by adding, editing, or deleting codes according to the outcome of the discussion.

Table 1: participant overview

ID	Participant	Role	Institution
1	Mr. S	Project Manager	Local Umbrella Organisation <Name>
2	Mr. R	Regional Coordinator	Local Umbrella Organisation <Name>
3	Mr. B	Manager	Sports Association <Name> with > 50 members
4	Ms. S	Manager & Training Group Leader	Sports Association <Name> with > 500 members
6	Mr. G	Manager & Training Group Leader	Sports Association with > 450 members

7	Ms. K	Sports club member	Sports Association with > 450 members
8	Mr. D	Manager	Sports Association with > 200 members
9	Mr. R	Sports club member	Sports Assocation with > 200 members
10	Mr. F	Manager	Sports Assocation with > 80 members
11	Mr. B	Sports club member	Sports Assocation with > 80 members
12	Mr. U	Researcher in HCI	University of <Name>
13	Ms. J	Researcher in HCI	University of <Name>
14	Mr. C	Researcher in HCI	University of <Name>
15	Mr. F	Researcher in HCI	University of <Name>
16	Mr. A	Researcher in HCI	University of <Name>
17	Mr. P	Co-Founder	Sports Equipment Company <Name>
18	Mr. T	Co-Founder	Creative Management Solutions Company <Name>
19	Ms. M	Researcher and Project Manager	Creative Management Solutions Company <Name>
20	Mr. M	Researcher in Sport Science	Technical University of <Name>

Results

In the following, we present our findings in relation to our research questions and the connected categories, which describe the individual adaptability and social interactive as the different requirements to led to the design and the technical infrastructure.

Individual and Institutional Customizability

The conducted interviews showed that there is a rising importance of digitalization within sports associations. Mr. D, the manager of the senior hiking sports association, explained: *"The tendency of digitalization has to happen within the next years. It is essential for sports clubs to keep their members and offer something attractive".*

Similarly, Mr. B, the manager of a sports association founded in 2017, stated that additionally to the regular training practices, they *"want to achieve a digital regularity"*. The most common reason for digitalization amongst the interviewees was the facilitation of data collection and thus training optimization and analysis. Most of the *"athletes that are to some extent ambitious already use sports watches"* described Ms. S, the manager and training group leader of a sports association with 500 members. Mr. G, a manager and training group leader of a sports association with 450 members, described how the athletes are mostly more digitally involved than he is when it comes to collecting data:

"Almost all of them have sports watches now. When they are done with their training, their watches show their timing. They tell me what the watch says and I note them into my chart by hand". Furthermore, Mr. G wished for a possibility to immediately transfer the athletes' data to his technical device and continued to express: *"It would be sensational if I could immediately analyze their data and my feedback in return would be instantaneous and always accessible"*. The use of technology was not only perceived as

convenient for the sports group trainers but also for the athletes themselves. As Mr. G ideated:

"*If the performance-driven athletes could see their development within the last weeks. What kind of training was beneficial or what do I still need to improve? Where are my weaknesses? Where are my strengths? And to be able to analyze that and compare it to another athlete that might have similar abilities*".

Besides the facilitation of training analysis, Mr. B emphasized the possibility of using that data to create individualized training offers through *"an app, based on the scope of previous training"*. During the workshop, one participant suggested using your own data for a *"virtual race* against *the own personal best"*. Ms. K, who is a sports club member herself, pointed out the recent importance of collecting data for the sake of sharing it online: *"If you did not record and upload an activity, it does not count"*.

During the interviews and the workshop, the participants were asked to name what they consider to be the most essential functions and technical requirements of sports wearables. Mr. G emphasized the importance of *"a stopwatch to measure lap times"*. Ms. S mentioned the importance of a *"route map"* and further explained, *"it is essential to explore new routes or retrace them"*. During the workshop, one participant stated: *"The wearable should convey some kind of diagnosis or motivation without the necessity to look on my watch"*. The placement of the wearable is essential, as Ms. S stated: *"As a runner, everything that is dangling and jingling bothers you. There is nothing worse than something dangling on you while you run"*. She concluded: *"It is annoying how you always need three technical devices to do something. There should be one device with everything I need implemented"*.

Social Connectedness and Motivational Aspects

The manager of a triathlon sports club, Mr. B, stated during the interview that *"feedback received through technology might be motivating but it is not essential"*. Referring to digital sports watches used by members, he concluded:

"If you improved, you'll immediately get feedback on your watch. That can definitely motivate but to be honest, when looking at the whole season, the most motivating part is the competitions".

The competitions turned out to be the most prominent factor in all of the interviews we conducted. Mr. B mentioned in the initial interview, "*I know that the athletes miss one thing most during the pandemic: The competitions"*. Due to the COVID-19 pandemic, training and competitions no longer took place, leading to interviewees pointing out how the athletes miss training and competing with all its long-term individual and social preparations and implications). During our Co-Design Workshop, one training group leader stated: *"In times where the direct comparison is not possible, the digital one is even more important"*. Similarly, it was mentioned by Mr. G that the *"community that wants to compare themselves is very big"*.

Competitions were described as not only being motivating because of wanting to win but also the social component, *"to be together and talk about the* great *competition afterwards"* as argued by Mr. B. Other factors mentioned were the involved playfulness

and related motivational aspects. For example, Ms. S mentioned that, "*I always say: Adults turn into children when involved in activities that include competition",* and that in terms of group dynamics and competitions, "*everyone automatically wants to be a part of it"*.

As seen in the foregoing statements, competitions were identified as an essential motivator for most athletes. Yet, not only for the reason of competing. It turns out to be of similar importance to cooperate as a team as well as to experience the competition together. As Ms. S, the manager of a sports club with approx. 500 members stated: *"Most members are in the* sports *club because they want social connection"*. The social connection includes both the connection to other members as well as their connection to the trainers. As one manager pointed out: *"We realized that we have to keep in contact or else our members will leave*". Keeping in regular contact with their members has proven to be especially difficult during the COVID-19 pandemic. Thus, sports clubs changed their way of communicating with the members. The interviewed sports associations used different infrastructures to stay in contact with their members and offer them activities during COVID-19 restrictions. The range of improvised actions varied significantly.

One manager from a senior hiking association reported that *"we needed to create a telephone list"* to stay in contact. Another manager explained that they are *"communicating with the athletes via chat messengers"* and tried to provide alternatives to the training and competitions that no longer took place. Ms. S referred to an initiative of the regional umbrella sports association, which coordinates projects and activities across all sports associations in a region. They offered some projects for the sports clubs to participate in such as *"a fitness application that allowed you to create teams and within a time span of 8-12 weeks you could collect points as a team"*. Some sports clubs even came up with their own events. One triathlon club challenged their members to be as active as possible for a time frame of two weeks and counted the total of kilometers they completed running, swimming and biking: *"This initiative received a lot of positive feedback"* stated Mr. B, and further explained that they rewarded their members, "*we said: Great, in total all of you completed 800 kilometers. And then we rewarded them by placing gifts on their doorsteps"*.

The interviewees emphasized the importance of integrating a social component into sports technology. One training group leader pointed out that "*communication between athletes that are en route alone is very important*". Similarly, Mr. G, the manager of a sports club with 450 members stated:

"As a cyclist, for example on racing bikes or in groups, it is fairly difficult to communicate with one another. Especially if there is a pothole or some other obstacle. There are certain hand signals but to use them you have to let go of the handlebar. It would be great if that could be facilitated via sports technology".

Mr. B mentioned the existence of some technologies that have online functions allowing competition or cooperation with other athletes: *"While indoor cycling, you're not cycling alone. You're actually racing with other people all around the world"*. During our workshop, we explored several other scenarios that technology could achieve with the participants. One workshop attendant ideated: *"It would be great to compete in a race*

as a team, so that everyone is wearing augmented glasses and can see where everyone else is". Another interviewee suggested the following scenario:

"If you could meet together virtually, 2 pm Saturday, us three will meet for running, maybe two will take the bicycle, five are hiking with their parents, but all together. Having digital groups that can meet". Another suggestion was to create a social sports platform that allows people to “create small challenges, for example jumping across three rocks, and if you complete other people’s challenges, you’ll get an achievement”. One more idea that came up in the workshop was to design “an active digital lunch break with friends that work in another place”.

Technical infrastructure

The technical infrastructure of the designed and developed system consists of three main elements, which are interconnected: AR glasses with different multimodal input options (gestures), a smartphone application to create groups, organize challenges, track records, and a PostgreSQL database, which is collecting and forwarding activity data (GPS, average speed) from multiple users to connect user synchronously from different places on comparable running routes that are chosen within the app. The system can be used as a navigation and orientation system (near-real-time positioning) and synchronize movements of multiple players between the real and virtual worlds to initiate a digital-supported marathon for users who are in different places in the world. Compared to existing AR interfaces in gaming contexts, the input modalities allow for more immersive interaction during outdoor activities. Similarly, the wearable interface enables the user to move more freely and naturally without having to hold additional technology.

Figure 2: AR glasses with a monochromatic field of view

System Components and System Design

The system consists of AR glasses and a smartphone application to command the system as well as to store and analyze data (see Figure 2). The data can be used to analyze and present individual results, share achievements within a group and derive long-term activity trends from strengthening health awareness.

User-friendliness was a design objective in the presented work. We designed the system so that the interaction of the system highly correlates with the naturalness and simplicity with which a user can operate it (intuitive & multimodal control via touch or swipe gestures). Within the system, both active and passive interaction modalities (sensor, actuator, device) were developed to enable users to interact directly (actively)

and indirectly (passively) with the system and the multi-user interface. The route planning system, which visually displays the selection made by the user via the AR glasses and provides additional, supplementary information via a voice output, ensures that the additional information provided by the voice output also matches the route selection made, even if the user performs different actions in quick succession. The interaction with the AR system was designed to command via voice and motion commands. We designed the system to ensure that the user is provided with the best possible combination of available modalities for processing a specific task before and during the training activities without stopping the outdoor activity. For this purpose, the development of multimodal interaction enables accessibility and increases the efficiency and ease of use as well as the flexibility of human-technology interfaces.

The smartphone application itself (see Figure 3) is structured so that user always sees the current navigation menu at the top. At the bottom, the permanently visible main navigations bar is always accessible, regardless of where the user is, and is designed with icons and texts aligned in a row. These elements are the main elements (dashboard, navigation, activities, settings, communication, team) of the application and should be easily accessible for the user to operate through different functions quickly.

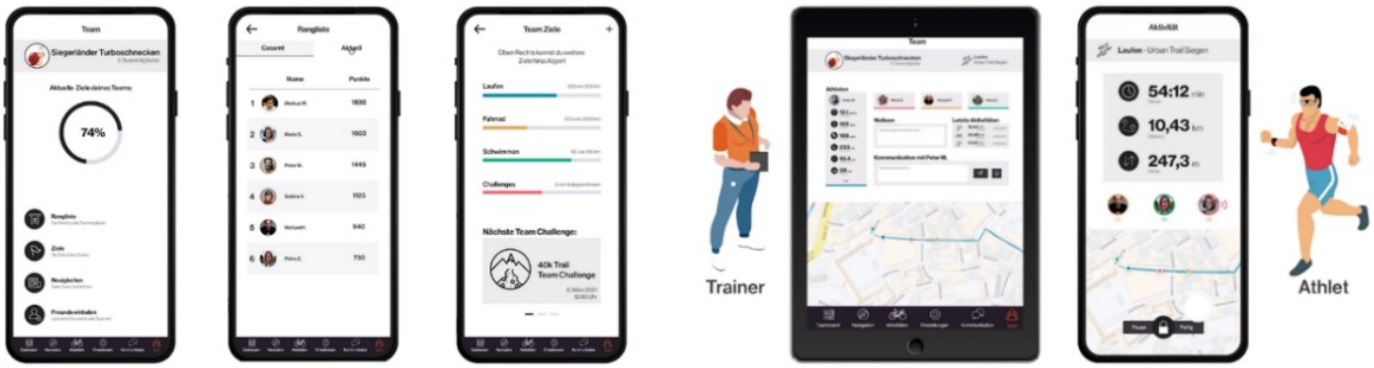


Figure 3: Smartphone App Overview

Conclusion

To conclude, our work presents a multi-user and multi-device AR technology intending to make PA more enjoyable. Hence, based on an immersive and multi-user capable AR technology, an innovative, individualizable opportunity of movement and cognitive training for health promotion was created. These multi-user sports- and exercise-related applications to be developed will be researched with regard to their suitability for everyday use and user acceptance of AR-systems as well as their individual physiological and social-emotional effects and evaluated in an upcoming proof-of-concept. The suggested scenarios may serve as a blueprint for further development scenarios such as an AR-based marathon, biathlon, or triathlon or interactive scenarios of experience-oriented discovery at the point of interest, such as AR-supported city tours in urban environments or digital tools in schools or inclusive settings.

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