Cycling is a Collaborative Sport and Cycling HCI Needs More Collaboration Research

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Our team has recently completed a systematic review of technology designed to support collaborative physical activity. We are in the process of submitting the full article for publication, and this position paper reports specifically on the findings of the systematic review pertaining to cycling. Due to the collaborative nature of cycling as a sport, we anticipated finding numerous research papers related to technology to support cyclists as they ride together. Following PRISMA guidelines, we systematically searched four databases using broad inclusion criteria, reviewed 2,571 studies, and identified only four papers related to collaborative cycling which met our criteria of supporting synchronous riding either in person or remotely. The findings suggest that there are many pressing needs for HCI research in collaborative cycling and that we have not yet begun to fully harness the potential of novel technologies to support people in riding their bikes together.

CCS CONCEPTS • Human-centered computing

Additional Keywords and Phrases: Cycling, Bikes, Collaboration, Systematic review, Collaborative Physical Activity

1 INTRODUCTION

Cycling is highly social and provides unique benefits that allow individuals of different fitness levels to be physically active together. Through drafting (the practice of positioning oneself in the aerodynamic slipstream of others to go faster for less effort), or through equipment choice such as e-bikes, cyclists of a wide range of fitness levels can ride together successfully [1, 2]. This affordance stands in stark contrast to other forms of aerobic physical activity such as running,

where participants of different fitness levels typically are not able to stay together. Research has shown that cycling is a safe form of aerobic physical activity for all ages [3].

Studies indicate that incorporating positive social elements improves the continuity of engagement in physical activity [4, 5]. These social components may include collaboration, which is the focus of the in-progress systematic review described briefly in this position paper. In the context of physical activity and fitness, there is no universally agreed-upon definition of collaboration in physical activity. However, it is commonly defined as a shared endeavor where two or more individuals work together to accomplish a task assigned to a mutual goal and their collective actions can positively impact the success of other members [6].

Collaboration differs in important ways from competition, cooperation, and the broader term of social support. Collaboration in physical activity stands in clear contrast to competition, where one person's actions prevent another person from being successful in achieving their goals. Competition is central in sport, but for some individuals, loss during competition can cause a decrease in intrinsic motivation or perceived competence, especially for individuals unaccustomed to or uninterested in competitive environments [7]. Technology that aims to enhance physical activity through competition uses features such as leaderboards and incentivization, often delivered through mobile applications or exergames [8, 9]. Our literature review excludes research on competition because our goal is to study collaborative support.

A more nuanced distinction lies between collaboration and cooperation. During cooperative physical activity, the success of one individual is positively correlated with the success of others, a feature it shares with collaboration and not competition. A cooperative environment can facilitate stronger benefits and feelings of achievement by providing more opportunities for success compared to playing individually [5]. However, cooperation often involves participants engaging in activities asynchronously toward a shared goal (e.g, a team mileage per week) and never engaging in collaborative activities.

Collaboration is one form of the much broader phenomenon of social support, which refers to any activity that helps an individual adopt and/or maintain a specific behavior [10]. Social support has been shown to be a significant factor in sustaining physical activity [11, 12] and can include emotional support (e.g., friends and family encouragement to be persistent in executing physical activity), informational support (e.g., raising awareness, providing information and instruction), and companionship (e.g., participating in the same physical activity). Social support plays an important role in collaboration, but as we will discuss shortly, it is possible for technologies to foster social support without supporting collaboration (for example, through social media people can give each other "likes" for individual physical activity).

This position paper focuses on the following research question: What technologies have been created to promote collaborative cycling? We define collaborative cycling as follows:

- Two or more participants ride bikes synchronously (at the same time).
- All participants share a common goal, not a competitive goal.
- Each participant engages in a physical activity task. Therefore, interaction via social media or post-activity interaction only does not qualify.
- No intrinsic power imbalance such as coach-athlete should be present.

2 SYSTEMATIC REVIEW PROCESS

To find related papers to investigate our research questions, we looked at four main databases, ACM, IEEE, PubMed, and WebofScience. All searches were completed by November 30th, 2023 and included all papers published within the last 10 years (2013 to 2023). We used three main search terms, each representing one portion of our objective: "Technology", "Collaboration", and "Physical Activity". We targeted terms that indicated the technological tools used to monitor

biofeedback data or deploy interventions through them. Typically, these tools involve mobile technologies that individuals can interact with easily anywhere and anytime while engaging in physical activity. “smartphone”, “smartwatch”, “tablet”, “tracking device”, “pedometer”, “application”, and “website” are some examples of the terms we used. Search terms including "cooperation," "group," "family," "peer," and “social support” were used to find papers about collaboration. We sought to include words like “exercise,” “sport,” and “fitness” in the physical activity category, in addition to certain aerobic activities such as “cycling,” “walking,” “running,” and “dancing.” The goal of this strategy was to achieve thorough coverage of research articles written in these particular fields.

We used a number of filters, restricting the publication year to the recent ten years (2013–2023) and only incorporating papers written in English, in order to remove irrelevant studies. We used flexible inclusion criteria that did not require any particular study design, sample size, or target demographic. We eliminated papers from disciplines that were unrelated, including chemistry, pharmacology, and rehabilitation.

3 RESULTS

A comprehensive search using four databases yielded 2,570 papers and we identified one additional paper later that was not included in the databases, for a total of 2,571 papers considered. After removing 160 duplicates from the original 2,570, our search identified 2,410 potentially relevant articles. These were then scanned during an initial title and abstract screening, where 2,142 were removed. Next, 268 studies were then subject to a full text review, of which 258 were removed because they did not include any technology, were materials outside the scope of this review (e.g., books, reports), or were systematic or scoping reviews. After careful examination, a total of 11 (10 from the original search plus the one we found that was not included in the databases we searched) studies met the inclusion criteria for collaborative physical activity in general. Of these 11, four included cycling. The remainder of this position paper focuses on those four papers.

To facilitate collaboration among pairs of cyclists, Agharazidermani et al. [13] tested a novel mobile application with four dyads of competitive and recreational adult cyclists. Using the mobile application, the two cyclists in each pair rode together and saw each other’s heart rate in real time. The app treats participants' fitness levels as unique to each individual and supports heart rate zone setting on an individual basis. With this information, the novel app facilitated the cyclists' ability to track each other's data and adjust their own effort in turn, with the goal of maintaining the same relative heart rate zone during an outdoor co-located ride. The technology relied on a heart rate sensor chest strap that was connected to the smartphones used by the cyclists.

Baduna et al. [14] proposed an app to promote outdoor collaborative physical activity (e.g., cycling, walking, and running) by helping a group of users detect each other’s location. The proposed app, “Track your friends,” provides a location tracking system as well as visualizations of some metrics (e.g., speed, time, and distance). Using the app, users can create events, invite friends to take part in various physical activities together, communicate with one another, and share GPS data while doing physical activity.

To facilitate collaborative high-intensity interval training, de Souza et al. [15] designed a cycling virtual exergame allowing players to pedal on their stationary bicycles and collaborate with others to fight a monster. Wearing a VR headset, the players find themselves immersed in the “World of Riders,” pedaling their stationary bicycles in the real world while paddling their boats on a lake in the VR environment. High-intensity intervals are comprised of a specific amount of high intensity exercise and a recovery interval after. In the game, the player must paddle hard to collect a missile. Then, once the player’s boat gets into the shooting booths, the player needs to stop paddling and this break serves as their recovery interval.

Walmink et al. [16] developed a system that displays each cyclist's heart rate on the back of that cyclist's helmet, where it is visible to a cyclist behind them but not to themselves. The display was a phone mounted on the back of the cyclist's helmet showing their heart rate number and a graph of the past minute's heart rate changes. In a study with pairs of cyclists, their goal was to stay within the same heart rate zones. They had to position their bikes in a way that allowed the trailing cyclist to read the lead cyclist's heart rate, and they shared these heart rates through verbal communication.

4 DISCUSSION

These four cycling-related papers represent exclusively early-stage research with either no empirical results or exploratory empirical studies with no formal experimental design. Baduna et al. [14] was a design proposal with no apparent implementation for their app. One step farther in development, de Souza et al. [15] report on an implemented system but did not describe any deployment to users. From those two papers, we can extrapolate design ideas and implementation details but no empirical evidence.

Two of the papers provide empirical evidence of a qualitative nature as to the effectiveness of their technology to support collaborative cycling. Agharazidermani et al. [13] observed a higher frequency of social communication in comparison to communication that was task-oriented. Consequently, they believe this finding suggests that individuals are able to engage in more social conversations during cycling if they have real-time collaborative data, as opposed to being focused on verbally exchanging heart rate. In addition, Walmink et al. [16] reported that being able to see someone else's heart rate can help with engagement in social exertion as well as facilitate empathizing with another person. To know and discuss their heart rate, the cyclist had to position themselves in front of their partner who could then read their heart rate from the back of their helmet. The authors note that these temporal and spatial limitations would have influenced the heart rate itself and the interpretation of it, but they claim that the dialogue of telling each other their heart rate enriched the communication between the pair.

5 CONCLUSION

On the one hand, the results of our systematic review are exciting: of 11 total papers identified on technology to support collaborative physical activity, 4 of them included cycling and among those, 3 focused exclusively on cycling. On the other hand, this number of papers is very small given the number of manuscripts originally considered based on search results, indicating that there is much room for research on Collaborative Cycling HCI. Moreover, the papers were all at relatively early stages, with two design proposals having no empirical results and two early exploratory studies with small samples. This finding suggests a tremendous opportunity for programs of research in collaborative support for cycling that move beyond exploratory studies with prototypes into understanding the causality between the novel technology and outcomes of interest. The Cycling HCI community can seize this opportunity to advance the state of the art in support for collaborative cycling, hopefully bringing the many benefits of bikes to people in a way that leverages the power of social support for physical activity.

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