SilverCycling: Evaluating Persuasive Strategies to Promote Physical Activity among Older Adults

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Figure 1: A participant of the preliminary study using our prototype

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Abstract
We present "SilverCycling", a system consisting of an augmented portable bike and a persuasive see-through mirror aimed at encouraging older adults to be physically active. We evaluated the perceived persuasiveness of seven commonly used persuasive strategies (N=9) within SilverCycling in order to elicit the most relevant ones for a field test in future work. We found that social strategies are preferred over non-social ones and that strategies using extrinsic motivators like virtual rewards should be avoided.

Author Keywords
Persuasive Technology; Seniors; Cycling

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
Modern societies are increasingly prone to physical inactivity caused by more and more people leading sedentary lifestyles [13]. This was shown to lead to a wide range of health problems, including cardiovascular diseases, obesity and many other chronic illnesses [4]. Given that activity levels progressively decrease with age [7], encouraging older adults to be physically active is particularly important.

Self-monitoring ("SFMG"): The distance cycled for today, yesterday and the whole week is shown. Additionally, a bike icon blinks when a user is cycling.
Praise ("PRAS"): A motivational message ("Good job! You already cycled <distance>. Keep cycling!") is shown to the user after cycling a certain distance.
Reward ("REWD"): The system rewards users with points for cycling certain distances. Points unlock achievements.
Competition ("CMPT"): A real-time leaderboard based on the cycled distance is shown. Each users' personal information(avatar, username, current activity status, abbreviated "PI" subsequently) is also shown.
Comparison ("CMPR"): The accumulated traveled distances of all users and PI are shown without ranking them.
Cooperation ("COOP"): A list of users, including each users' PI, is shown, without cycled distances. Moreover, a team goal is shown that needs to be reached by all users together.
Normative Influence ("NORM"): Active users and their PI are shown, without showing any information about the distances cycled.

Sidebar 1: Implemented persuasive strategies

Although past research has addressed encouraging physical activity [8], most studies have focused on a younger audience [16]. Moreover, existing research was often theoretical in nature, e.g. it made use of storyboards to investigate the effectiveness of different motivational affordances [2, 12], posing the question of how far such findings are transferable when implemented and thereby providing older adults the possibility to *experience* them. To allow older adults to try out commonly used persuasive strategies, we created "SilverCycling", a system consisting of an augmented portable bike and a persuasive see-through mirror aimed at encouraging older adults to be physically active. We performed a preliminary user study (N=9) to test the persuasiveness of these strategies in order to gain initial insights about which are relevant within SilverCycling and thus should be used in a field test in future work. We found that social strategies are preferred over non-social ones, that self-monitoring is perceived particularly positively and that virtual rewards should be avoided.

Related Work

While persuasive strategies in general lead to positive effects [8], studies also suggest that people are diverse in how such strategies are perceived [12, 11]. Orji et al. [12] analyzed the persuasiveness of ten strategies using storyboards. While findings show that users react differently to each one, it is unclear to what extent this is true for older adults. Moreover, since the strategies were presented in storyboards and could not be tried out, implementing them in a real system seems to be a logical next step.

Concerning older adults and persuasive technology, literature shows that there are different needs and preferences. While De Schutter and Vanden Abeele [5] point out that connecting with others, self-cultivation, and being able to contribute to society are important, Birk et al. [3] show that motivations to engage in such systems change with increasing age, from focusing on performance towards focusing on enjoyment. This is underlined by findings from Altmeyer et al. [2], indicating that the importance of positive social relationships in such systems increases throughout the lifespan. These findings suggest that the perception of persuasive strategies might differ among older adults, which supports the need for investigation.

To conceptualize SilverCycling, we considered the specific needs and barriers of older adults. As Romero et al. [14] showed that elderly people fear being stigmatized when using technologies that emphasize their need for help, our system works without any complex interaction and focuses on using familiar artifacts (a mirror) to enhance its acceptance. To reduce the "environment barrier" established by Schutzer and Graves [15], which states that seniors tend to be more active, if they have direct access to perform an activity, we decided to use an augmented portable bike that can be placed in older adults' homes.

System Design

SilverCycling consists of an augmented portable bike that enables continuous tracking of activity data and a mirror that allows for this data to be presented to the user using one of seven commonly used persuasive strategies [8]. Sidebar 1 summarizes how each strategy was realized.

Augmented Portable Bike

For our prototype, we used a portable bike which we equipped with an Arduino, a WiFi chip and a reed switch to track the distance cycled. As tracking physical activity manually is especially burdensome for older adults [17], the bike connects wirelessly to the persuasive mirror and continuously tracks and communicates activity-related metrics. All communication and tracking processes are done automatically and in

Figure 2: Screenshot of the competition strategy shown on the persuasive mirror

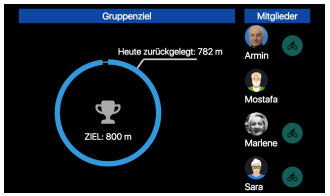

Figure 3: Screenshot of the cooperation strategy shown on the persuasive mirror

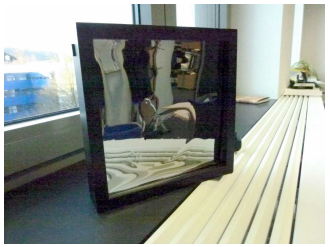

Figure 4: Persuasive mirror

Sidebar 2: Pictures of our system

realtime, requiring minimal cognitive effort, as the interaction with the system happens indirectly by cycling the bike without any additional interaction. Equipped with a 3500 mAh battery, the prototype does not need to be charged for years, since the microcontroller goes into a low-power deep sleep mode as long as no user is cycling.

Persuasive Mirror

The central component of our system is the persuasive mirror displaying activity-related information. As a first step, we used the mirror as a test-bed to evaluate the perception of the aforementioned persuasive strategies. For example, the competition and cooperation strategies are shown in Figure 2 and Figure 3 respectively. Screenshots of all strategies are available on figshare[1]. Since technology acceptance is especially an issue when designing for older adults [14], we decided to use a mirror in order to enhance the acceptance of the system by using familiar artifacts [18], and a digital display to present information through the mirror without exposing any electronic components of the system. We used a wooden frame to house all the components, including a two-way mirror, a 7-inch LCD display, and a Raspberry Pi 3, to which the activity data from the bike is sent. The final prototype can be seen in Figure 4.

Preliminary Evaluation

We aimed to assess the effectiveness of each strategy within SilverCycling in order to decide which ones are relevant for an in-the-wild evaluation in future work.

Hypotheses, Procedure and Method

The hypotheses can be found in Sidebar 3. We established **H1** as previous work identified differences using a younger population [12]. **H1a** follows from [2], indicating that seniors prefer cooperation over competition (using storyboards to explain each strategy). **H1b** is based on the assumption that rewards are not perceived to be meaningful by seniors [2, 6]. **H1c** follows from [9], indicating that self-monitoring is perceived as intrinsically motivating by older adults. Lastly, **H1d** is derived from [2] showing the overall preference of seniors towards social strategies.

The study started with a questionnaire covering demographic data and self-assessed physical activity (using 5-point Likert scales). Afterwards, each persuasive strategy was shown on the persuasive mirror (the strategies were counterbalanced using a Latin square) and participants were asked to cycle for at least one minute. We made sure that core elements (e.g. rewards, text messages) were triggered within this time. For the social strategies, we created two dummy users (a female and a male). The initial distances for these dummy users in the competition/comparison strategies were set such that they were in the range of the participants' performance. When participants started to cycle, these distances increased in fixed intervals. After trying out each strategy, four questions followed (using 7-point Likert scales) to measure the perceived persuasiveness using the same instrument as in [12]. To ensure that participants understood each strategy, we showed textual representations for each one and asked participants to identify the strategy that was shown.

Results

A total of 9 participants (5 females, 4 males) took part in the study. Their age ranged from 57 to 87 years old (M=70.6, SD=11.5). Even though participants thought they led fairly active lifestyles (M=4.5, SD=1.43), the self-reported moderate physical activity frequency per week (M=2, SD=1) was less than recommended (5 times/week) [1]. The persuasive strategies were successfully assigned the correct textual

[1] http://goo.gl/tRq5sW, last accessed April 19, 2018

Hypotheses in the preliminary evaluation

H1: There are differences in the perceived persuasiveness of the strategies

H1a: Older adults prefer cooperation over competition

H1b: "Virtual rewards" is the least persuasive strategy

H1c: "Self-monitoring" is the most persuasive strategy

H1d: Social strategies are preferred over non-social ones

Strategy	Mdn	p	r
SFMG	6	.01	.60
REWD	2.25	.02	.53
PRAS	4	.55	.14
NORM	5.5	.03	.50
COOP	6	.56	.45
CMPT	5	.04	.47
CMPR	6	.01	.60

Table 1: Median perceived persuasiveness on a scale from 1 to 7 (Mdn), p-values (p) and effect sizes (r) of Wilcoxon signed-rank tests against the neutral choice of 4 for each strategy. Significant effects are colored (red for negative, green for positive perceptions) and bold.

Sidebar 3: Hypotheses and results

representations($\chi^2(6)$=51.4, p < .01), indicating that participants understood the the strategies [12].

To assess the perceived persuasiveness, we followed [12] and calculated the average of each of the four items composing the perceived persuasiveness scale for every strategy. As revealed by a Shapiro-Wilk test, our data was not normally distributed. Therefore, Friedman tests were performed to test for statistically significant effects and Wilcoxon signed-rank tests for post-hoc analysis.

We found a significant difference in the perceived persuasiveness of the strategies ($\chi^2(6)$=18.5, p < .01), **supporting H1**. The post-hoc analysis revealed that **self-monitoring** was perceived as more persuasive than the reward, praise or comparison strategy (for all p < .05 and effect sizes r >.45). Moreover, the **reward** strategy was perceived as less persuasive than normative influence, cooperation, competition, and comparison (for all p < .05 and r >.50). Also, the perceived persuasiveness was higher for **comparison** than praise (p < .05, r=.50). Furthermore, there were no differences between the cooperation and competition strategies (Z=-.35, p=.73); thus, hypothesis **H1a is not supported**.

To get an overall impression of which strategies were perceived as persuasive, we compared the scores for each one against the neutral choice of 4, similar to [10], using Wilcoxon signed-rank tests. Results can be found in Table 1. We found that the reward strategy is significantly below the neutral rating of 4, making it the least persuasive one, **supporting H1b**. On the other hand, self-monitoring, normative influence, competition and comparison were perceived as most persuasive with median ratings significantly above the neutral choice of 4, **supporting H1c**. Regarding the difference between social (normative influence, cooperation, competition, comparison) and non-social (self-monitoring, reward, praise) strategies, we found that social ones (Mdn=5.56) are preferred over non-social ones (Mdn=3.92; Z=-2.37, p<.05, r=.56), **supporting H1d**.

Discussion and Limitations

We learned that rewards should be avoided, which is explainable by previous work, suggesting that older adults may not see value in earning virtual rewards [2]. We also expected older adults to prefer strategies building on cooperation over competition. However, in contrast to related work [2], participants liked competition while no preference for cooperative elements was found. As the sample size was rather low and the cooperation strategy was also perceived well, a higher sample size might lead to detecting the expected effect. Nevertheless, social strategies were preferred over non-social ones, which was to be expected given previous work [2]. The main limitation is the low sample size. As the study was meant to elicit strategies for a field test of our system, it should be regarded as an initial, preliminary exploration rather than a mature investigation.

Conclusion and Future Work

We evaluated the perceived persuasiveness of seven persuasive strategies to encourage older adults to be physically active. In contrast to previous work, we implemented these strategies to allow participants to try them out. We found that there are differences in the perception of those strategies: While rewards were perceived to be least motivational, social strategies as well as self-monitoring were perceived particularly well.

Since competition and cooperation achieved positive ratings, we will integrate both and combine them them with self-monitoring in our final system. Afterwards, we will perform a field study to investigate actual effects of our system on physical activity behavior of older adults.

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