Context of Use and Timing of Social Comparison Techniques in Behavior Change Support: A qualitative systematic review

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ABSTRACT
This paper aims to examine the timing and contexts of use of social comparison techniques in supporting behavior change. Timing is evaluated through stages of the behavior change process in accordance with the Transtheoretical Model, while context of use is defined through the level of publicity at three levels: public, semi-public and private. A qualitative systematic review was conducted of prior research dealing with applications featuring social comparison techniques. Through a systematic search strategy, eleven IT artifacts were selected for analysis. Then, patterns of use were analyzed so as to identify experiences on proper timing and context of use. The analysis shows that the technology placed in public spaces is suitable mainly for the first stages in the behavior change process. A private context of use is preferred in later stages.

Author Keywords
Behavior change; social comparison; HCI; social visualization; design, interaction design.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces --- User-centered design;

INTRODUCTION
Global and local change towards a healthier and more ecologically sustainable lifestyle is the goal in many developed countries [8, 9] and increasingly so also in the developing world. Behavior change is relevant in people's lives either because they are triggered to change for example by following a doctor's advice to alleviate health problems, or because they voluntarily want to change due to their personal life-goals, for example, by consuming less electricity for ecological reasons. However, as common as it seems to find a person who wants to change, it seems equally common to find people who have problems in succeeding in changing and sustaining their new behavior. Nowadays, there is rapidly growing technology-based support that claims to assist people in behavior change by persuading and motivating them to start or continue their desired behavior [6, 11, 24].

Even though information technology is a relatively new field, human behavior has been the subject of study for decades in psychology and social sciences. These fields study the person and our interactions with the society in which we live [1, 10]. Through these theories it is shown that the behavior of an individual cannot be understood in isolation from the society and social environment where the individual lives. The behavior of the individual has been shown to be highly dependent on social structures and the behavior of other people. More specifically, according to social comparison theory [10] a person cannot fully perceive herself without comparing herself with others. Even more, people are social beings and they are willing to change in order to be members of a group (nominative influence) or in order to achieve a feeling of being right (informative influence) [1].

Technology and theories on social influence and social comparison can be effective tools to support the efforts of people who try to change their behavior. Availability of digital data and computing resources provide us with an opportunity to visualize and present user data in a way that has not been possible before. These possibilities can provide unique opportunities to explore the power of social influence through aggregated data about other people. This paper aims to answer, through a qualitative systematic review [17] of prior work, the following research question:

Is there a link between timing and context of use in behavior change applications?

In our analysis, we will focus especially on visualizing the individual's data in comparison with the group or with the aggregated values of the group, i.e. we exclude the applications that only look at person-to-person relationships. This restriction was made because we wanted to focus especially on the aggregated use of digital data, and the use of data visualization in presenting aggregated data. The Transtheoretical model (TTM) will be used as a framework to illustrate the different stages of an individual's behavior change, as well as the needs of the individual at each stage.

The results will highlight the link between the timing and context of use, i.e. during which behavior change stage have applications implemented in different contexts proved to be successful according to previous research. The results are useful to researchers and designers who design technology for behavior change, and who wish to use social influence as a design feature. The results summarize previous research and what kind of design parameters have proved to be successful in previous research.

BACKGROUND

The design of behavior change technology is commonly guided by different aspects of behavior theories. Many designs are focused on an individual's progress and self-tracking by helping people keep track of their own activities [2, 6, 12]. Others focus on moving the activities that a person wants to change from the unconscious to the conscious [5]. Some research focuses on different types of visualizations illustrating an individual's progress [3, 24]. In this paper, we want to explore closer the applications that utilize social influence - the influence people have on other people's behaviors, beliefs, or feelings [1].

One technique is to use a social platform to embed social influence in a behavior change application. People can use this platform to support each other in the behavior change process by sharing experiences and useful information [16, 19, 29, 30, 33]. This social platform acts like social media, such as Facebook. People can post information and have feedback, but it is hard to compare the information because it is not aggregated.

Another technique is to organize the available data, mainly by comparing the data of the user with the data of another user [28]. These applications give an opportunity to compare with another user, one at a time. However, these applications do not have algorithms to aggregate data, and therefore they cannot directly support the user in creating awareness of behavior within larger groups of people.

A third technique gives the user the possibility to see and compare the data of different groups, see themselves in comparison with the group and compare with other members of the group through aggregating the data of several individuals into data presentations that directly support the user in creating an awareness of group behavior or characteristics [4, 13, 14, 18, 20, 21, 23, 25, 27, 32, 34, 35]. For example, a person can see more than one individual of a group at a time, can make subgroups and compare one's status inside a group, which is cognitively easier than seeing only one other person's data at a time.

Most techniques refer implicitly or explicitly to the importance of timing in behavior change [7, 21, 22]. More specifically, the application should not interrupt the other activities of the user [24], or remind the user to do something that has already been done or intrude in their lives at an inappropriate time and cause negative feelings, such as embarrassment [6, 32]. Behavioral theories have also recognized that behavior change is a process [15, 31], and people have different kinds of needs in different phases of the process. The TTM presents the stages of an individual's behavior change not only in regards to the stage duration but also regarding the actions a person takes or is willing to take at each stage [15]. Based on the person's intentions and actions at each stage, the technology can be designed to support and motivate the actions taken towards the behavior change. Thus, the TTM can help to tailor technology for each stage.

The six stages of TTM as presented by Glanz et al. [15] have been used for categorizing the applications' suitability for each stage. Based on the TTM, behavior change is not a binary procedure where a person would change from behavior A to behavior B directly. This person needs to pass through stages and many times she returns to previous stages [15].

METHODOLOGY

We examine our research question by means of a qualitative systematic review [17]. We focus our review on previous studies of experiences adopting behavior change that featured social comparison techniques. The search strategy was iterative, and included three rounds. The first round was carried out with generic search terms: Visualization, visualisation, behavior change, behaviour change, behavioral change, behavioural change, persuasion, health, social influence and persuasive technology. Second round was done by combining more specific terminology of the fields that emerge from the studies found in the first round. They were: infovis, social capital, social visualization, social visualisation, social comparison, habitual behavior, habitual behaviour. The keywords of the first round were also included in the second-round search. Finally, a snowball technique was used in a form of analyzing papers that were found in the reference list of studies identified during the first and second round.

A targeted search of selected scientific databases (e.g. Scopus) resulted in poorer coverage, i.e. an unsatisfactory number of publications were found. Through a comparatory search strategy, Google Scholar proved to be more efficient in finding relevant papers, perhaps because of the multidisciplinary nature of the research question. Therefore, the first and second search rounds were done with Google Scholar. The aim was to find as many studies as possible and as relevant to the research question as possible regardless of into which specialized field the papers were categorized, the amount of citations they had, or when and where they were published. The criteria of inclusion and exclusion of a study were the following:

1. The paper reports experiences of validation of an IT artifact through a field study that provides experience data on its suitability for behavior change support. Designs that have not been tested in the field at least with a prototype were not included.
2. The IT artifact presented in the paper explicitly uses social influence techniques that compare the user with some reference group. Applications comparing only two single individuals have been discarded.
3. The paper makes it clear that the IT artifact influenced the users' behavior. Behavior change is perceived as any change between the stages of the Transtheoretical Model (TTM).

The first criterion of inclusion was analyzed by reading the methodology part of the paper. The second criterion of

inclusion required analyzing the artifact and its characteristics. The third inclusion criterion was examined through an analysis of choice of participants and sometimes through an analysis of the findings.

The first filtering was done based on the title of the study and abstract. The reading of the abstracts was done at the same stage as the reading of the title. The next stage was to read the study or at least until the point that one of the above criteria were not satisfied.

The papers have been categorized based on timing and context of use. The TTM stages were used for analyzing timing. Context of use was characterized as belonging to one of three categories: public, semi-public and private.

Timing was analyzed by identifying whether the application provided support for a specific TTM stage as follows:

1. Precontemplation: People with no intention to take any action towards the new behavior in the next six months [15]. As such, this person has no intention to use any IT artifact for changing behavior.
2. Contemplation: People who intend to take an action towards the new behavior in the next six months [15]. Thus, this person has learnt that a behavior change would be desirable, but due to a lack of motivation or knowledge, does not take actions that accrue to much effort. She is not likely to act to adopt an IT artifact to support behavior change, but is probably interested about the possibilities.
3. Preparation: People who intent to take an action towards the new behavior in the next month and they have likely taken unsuccessful actions [15]. Hence, this person might have already used and tested IT artifacts in the past but did not find the one that would be suitable.
4. Action: People who have been in the process of changing their behavior for less than six months [15]. Thus, this person likely found some IT artifacts that he/she can use. The IT artifact can be used as a motivating factor.
5. Maintenance: People who have been in the process of changing their behavior for more than six months but there is still a small possibility of relapsing [15]. As such, this person is using the IT artifact for motivation and for keeping track of his/her long-term progress.
6. Termination: People who are confident about their change and are sure that they will not relapse whatever the circumstances [15]. Thus, this person does not even need any IT artifact for motivation. He/she has successfully changed the behavior and the help that can be gained for the artifact at this point is just to keep track of his progress for reflective or other reasons.

Context of use was analyzed by recognizing the physical environment where the application was used in the field trial. The dichotomy public/private was used, with the public context described as "open, revealed and accessible", and privately private as "hidden or withdrawn" [26]. However, as the analysis progressed, a third category of "semi-public" emerged from the data. This category includes applications targeted at small groups (as, for example [23]). The three categories used in the analysis were defined as follows:

- Public: Public places are defined to be places that are open to everybody and are typically used by people who do not know each other, for example, train stations, airports, cafes, shops etc. We used this category to describe applications that were designed to be used in such contexts, for example, using public displays.
- Semi-public: Semi-public places are defined to be places that are used by groups of people who know each other, for example, the living room of a private home. These applications typically include features that support sharing of content and facilitating interaction between people who already know each other.
- Private: A context is defined to be private when the application is used by one person only, for example, with a personal computer or a mobile phone. In this category, we place constructs that are designed to be seen by one user only and, only if that user desires, the artifact can be shown to someone else actively by the user.

No testing period of any paper lasted more than six months. The categorization of the application conducted was typically based on user's opinions and researchers' observations. The analysis evaluated the findings on subjective experience and observed suitability of the application. All the applications had social comparison features, which aggregated the data of more than one individual in some data representation format.

RESULTS AND DISCUSSION

Table 1 lists the 12 studies that were selected to be studied as well as the search with which they were found (Table 1).

All the applications presented in these twelve papers use social comparison with aggregated data from more than one person. One of the applications was tested in two environments, public and private. The field trials presented in the papers lasted a maximum of six months. Therefore, none of the papers evaluated long-term behavior change, but

No	Title	Pub. Year	Description	Search Round
1	Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game [27]	2006	Software application for motivating people to be physically active by relating how active they are with the state of the avatar-fish. Social comparison is done by visualizing the fishes of other people in the same tank.	2nd round
2	Social Visualization Encouraging Participation in Online Communities [32]	2006	Software application for motivating participation in online communities for sharing studies by visualizing the activity of others with size and color of stars.	2nd round
3	Persuasiveness of a Mobile Lifestyle Coaching Application Using Social Facilitation [14]	2006	Software application for motivating people for a healthier lifestyle by supporting change in eating and activity routines. Users could compare their behavior with all the members of their team, and compare two teams.	1st round
4	Design and Evaluation of a Social Visualization aimed at Encouraging Sustainable Behavior [18]	2010	Software application for motivating people to adopt more eco-friendly behaviors by visualize the users as puzzle pieces. The more eco-friendly behavior someone had the more clearly their piece in the puzzle is visualized. In the opposite case the piece became darker and people could not see the complete puzzle.	2nd round
5	inAir: Sharing Indoor Air Quality Measurements and Visualizations [23]	2010	Device application for visualizing the air quality of a house or group of houses. Encourage indoor activities that can have an impact on the indoor air quality. The user could see the air quality of the other users in direct comparison to his/her own.	2nd round
6	UpStream: Motivating Water Conservation with Low-Cost Water Flow Sensing and Persuasive Displays [25]	2010	Device application for comparing user's water consumption to an average and to the user who was previously using this source of water.	Snowball
7	The Design and Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data [13]	2012	Prototype of a display application focusing on water consumption, visualization and placement of the device to influence water consumption activities. Among other things, comparison of water consumption of the family members presented in one screen.	2nd round
8	GreenSense: Developing Persuasive Service Technology by Integrating Mobile Devices and Social Interaction for Sustainable and Healthy Behavior [4]	2013	Software application for motivating people to be eco-friendlier and adopt a healthy lifestyle in the choice of means of commuting. The app visualizes the sum of transportation used, and allows the user to compare their individual profile with the profile of other users.	2nd round
9	Reveal-it!: The Impact of a Social Visualization Projection on Public Awareness and Discourse [34]	2013	Software application for projecting and presenting individual and neighborhood electricity consumption. The comparison can be done between neighborhoods, people, neighborhood's average consumption, and between neighborhood and people	1st round
10A	BizWatts: A modular socio-technical energy management system for empowering commercial building occupants to conserve energy [20]	2014	These studies refer to the same software application for influencing energy consumption in commercial buildings. The comparison can be done between many employees and between groups.	2nd round
10B	Effects of real-time eco-feedback and organizational network dynamics on energy efficient behavior in commercial buildings [21]	2014		2nd round
11	MyPosition: Sparking Civic Discourse by a Public Interactive Poll Visualization [35]	2014	Application where people can compare opinions about a specific subject and see in which group are belong.	Snowball

Table 1: The studies with the year of publication (pub. year) and a short summary. The numbers in the first column are the study codes used in this paper. The last column presents the round the study was found

No	Context of use	Technology implemented	Field of research	Usage based on behavior stage
1	Private Public	Computer screen Public display	Health	2, 3, 4, 5
2	Private	Computer screen	Other	2, 3, 4, 5
3	Private	Computer screen Cellphone screen	Health	2, 3, 4, 5
4	Private	Computer screen Cellphone screen (possibly)	Eco	2, 3, 4, 5, 6
5	Semi-public Private	Gadget - in semi public Computer screen Cellphone screen (possibly)	Health	2, 3, 4, 5, 6
6	Private Public	Gadget in public	Eco Health	1, 2 (public) 3, 4, 5, 6 (private)
7	Semi-public Private	Display in private	Eco	2, 3, 4, 5, 6
8	Private Public	Public small screen - tablet Cellphone screen Computer screen (possibly)	Eco Health	2, 3, 4, 5, 6
9	Public	Public projection (input data through tablet)	Eco	1, 2
10A and 10B	Private	Computer screen Cellphone screen (possibly)	Eco	2, 3, 4, 5, 6
11	Public	Public display	Other	1, 2

Table 2: Summary of context of use, used technology and TTM stage

used more subjective evaluation parameters in evaluating the success of the application. Table 2 summarizes the main focus of the study, the TTM stages targeted, and in which context the application was used.

In the following subsections, we discuss the patterns arising through this categorization and related analysis. We group our findings into two subchapters. The first subchapter discusses the link between the context of use and the TTM stage, i.e. in which context the applications targeted for each TTM stage were found to be successful according to the experiences reported in the papers. The second subchapter summarizes the interface technologies used in each TTM stage. Finally, we present a summary of findings.

Link between TTM stage and context of use

In the analyzed papers, all artifacts used in public spaces are categorized in the first two stages of TTM. The artifacts present less detail and a lower level of personalization than the ones that are used on higher TTM levels. The applications targeted for public spaces are based on impressive visualizations of data. Chen et al. [4] point out the importance of a direct, simple, but impressive visualization in applications targeted at public use. They found that the visualization needs to be direct and simple, for people to understand at once the meaning of the data represented, as well as impressive, for people to be interested in looking at the data. This has been confirmed in the two studies related to applications 9 and 11. The application nine [34] has been placed in lobbies and open areas during meetings, festivals and other specific events, while application eleven was placed in front of local cafes, shops and cultural centers [35] and was targeted at everyday use. In the study presenting application nine, the researchers found out that people who were visiting activities only for one day noticed the application before their scheduled activities and they came back to interact with it after their scheduled activities. On the other hand, people who were visiting activities for a period

longer than a day, were interacting with the application more extensively. Application eleven was placed in front of cafes and shops [35]. Due to the vivid visualizations, the application attracted people's attention. Not all the people who saw the visualization interacted with it. However, most of them discussed the subject of the visualization even if they did not interact with it directly. These discussions of people who did not interact with the application happened in the area where people could see the visualization. In both studies nine and eleven, the researchers did not help the users in using the application, but the users could cope by themselves. That was not the case in application six [25]. Application six presents an artifact that was not self-explanatory, but required researchers to explain to participants what the artifact represents. Through these discussions, they found that people were not well informed about global environmental issues concerning water consumption. The researchers concluded that these discussions and the whole experiment could influence some participants' behavior in the way that they become more informed about the connection between their behavior and environmental issues related to water consumption, and this could trigger them to proceed to the second stage of TTM. However, the artifact alone without the subsequent discussions would probably not influence a person in the same way.

As previous research shows, the use of specially designed visualizations in a public environment can facilitate discussions that can raise awareness and make people rethink their choices, attitudes and opinions [4, 34, 35]. This is all needed on TTM's stages one and two. Some of the applications have been designed to be used in stage two (applications 1, 2, 3, 4, 8 and, 10), but they do not include any specific techniques that would support the user in moving from stage 2 to stage 3, i.e. they do not have features that would specifically support the user in starting an action instead of just planning for it.

Based on the TTM, a person is ready to take actions towards a new behavior at stage three [15]. In other words, at level three people recognize that they need to change their current behavior and they need to do something about it. They are ready to ask for help. Moreover, at stages four and five people have difficulties in maintaining the behavior they want to acquire, such that the new behavior would be considered as permanent [15]. There is therefore in these three stages a risk of relapse, but the person will ask for help in order to maintain the new behavior. Most applications are designed for these stages (applications 1, 2, 3, 4, 5, 6, 7, 8 and 10). All these applications use different motivation techniques and different ways of representing social data, using social comparisons to motivate users to maintain the desired behavior. Some examples of motivation techniques used by the applications reviewed are: showing the individual that everyone in the group can influence the succession of the group's shared goal (applications 1, 3, 10), showing the relative position of the individual in the group by ranking the individuals, or to show where he/she is compared with the average (applications 2, 5, 6, 8, 10), and to make the individuals cooperate in order to have a reward were all of them to succeed in reaching the goal (applications 4, 7). These applications support people in stages three, four and five by having someone or something to motivate them or to be there at the time they might be thinking about giving up on maintaining the new behavior.

At these stages people actively try to change their behavior and use any help they can get. Moreover, the applications demonstrate different ways of visualizing detailed data about themselves, their group and the progress of both. Some of the applications show all the data at once (applications 1, 3, and 6), some provide users with the possibility to access details if they wish to (applications 2). Other applications change the format and the context of data based on the different choices of users (applications 4, 5, 7, 8, and 10). Application four supports three different forms of social comparison [18], which came about after it was pointed out by users in the usage study that they would appreciate being able to choose from even more comparisons than the ones originally proposed.

It is worth mentioning that applications 5 and 7 can be used in a semi-public context while they can also be used to influence the behavior of people in stages one and two. For example, if person A has one of those gadgets in the living-room and a friend (person B) visits A, then the exposure to the application can start a behavior change process for person B. First, since they are friends they would naturally discuss matters important to them, such as water consumption or air pollution. Second, since B would have already seen how gadget works in A's place, this might have triggered discussions. The same can happen with application six which is placed in a bathroom. One might argue that this can happen with any of these nine applications, which are designed for computers or cellphones, if someone happened to be in the right place at the right time and asked the right question of the person using the application. However, there is a difference between an artifact that has been designed to be displayed, by way of decoration, and an artifact that has been designed clearly for personal use with no intention to be shared with others. For example, applications eight and five can visualize generic data at a glance for more public use, and allow the user with an opportunity to see more specific data for personal use through interacting with the mobile or the computer version of the applications. Application seven [13] especially has taken the aesthetics of data representation into account. Moreover, the study discussing application seven is the only study where the authors asked the users where they would like to place the artifact. The answers differed. The most popular answer was in a place where all the people of the house would have access, the kitchen and hallway being the most common choices. There were only two out of the twenty users who wanted to put it in a place where it would not be seen by other people.

It seems that applications (1, 2, 3, 7, 8, 10) targeted at TTM model stages 3 to 5 are placed in private or semi-private environments where the user has immediate and direct access to them, or access to the application is connected to the activity that the application visualizes, or the application is used as a form of diary or progress indicator.

Stage six is the last stage in TTM. It describes people who have reached the behavior they want [15]. At this stage, people are not in immediate danger of relapsing into their previous behavior and the new behavior becomes unconscious. As such, they do not need any specific motivation to follow the new behavior since it is already part of their life. There is only one study [27] that referred explicitly to this stage, the study in that discussed application one. This paper uses the TTM model to evaluate the effect of the application on users who have been categorized during different TTM stages. The authors of this study point out that the application does not influence the behavior of people who are in the last stage of TTM model, for example, people who have been working out throughout their lives. However, they included the comments of users from stage six where they expressed enjoyment in browsing the graphical representations illustrating their behavior and that it made them reflect on what they can do to be even more active. Additionally, application six, which was installed in a household where tenants considered themselves as active in water conservation, showed that the tracking and the constant reminders can influence users towards their desirable behavior without them even realizing it. In this study [25] a user reported that his shower usage did not change during the experiment. However, the data collected showed a positive change. These experiences indicate that even when people at stage six are not in immediate danger of relapsing, they could be positively affected by an application that helps them reflect on their activities and become even more motivated. Keeping track of one's activities and thee outcomes of these activities can support the personal image that this person has of herself. Therefore, applications that can offer these kinds of functionalities can be helpful in this stage.

Finally, the behavior change as described in TTM is a process advancing from one stage to another. The target is always to reach the last stage. It has been shown [15] that people can go backwards in stages, for example, from stage five to stage four or three, but the model implies that people cannot skip stages while going towards stage six. This is logically built into the model, since a person (stage 1 or 2) who is not informed or well informed about the consequences of his/her behavior will never take any action towards changing them. As such, he/she will never get into the next stages. This analysis shows that applications targeted at individual use will be more suitable for stages three, four and five, since the individual is asking for support at these stages and he/she will use them, in contrast with the first stages, where the person does not have the same motivation to change his/her behavior. Instead, applications that promote awareness and help people understand the importance of a subject or behavior, without requiring any action by the individual, are suitable in the first stages.

Display technologies linked with TTM stages

In most cases visualizations presented through displays are used to present data to individuals. There was only one application that used an alternative user interface option, which was an ambient light (application 6) that indicated water usage. At TTM stages one and two, the applications used public displays, such as large public screens (application 11) or projections onto a big surface (application 9). There was only one exception, application eight, where the surface was the size of a tablet. However, the study reports no problems related to the size of the screen [4]. The experiences reported in the studies highlight that to attract people's attention, more vivid graphics and easy to grasp presentation of the data would be needed.

In the private and semi-private contexts that target TTM stages three and beyond, the information is presented mainly on a personal computer or on cellphone screens (applications 1, 2, 3, 4, 8, 10A and 10B). However, some of the applications (1, 8) also utilize a public display for some functions, where people can see individual or other people's aggregated data. For example, in application one the public display was used to present the progress of individual users. In application eight, the public display visualized a summary of the means of commuting for employees working at that work location. Application seven was a small domestic display placed in homes, visualizing water consumption by a device or by a person living in the home. It used, among others, a visualization metaphor of an abstract aquarium, which changed depending on the family's water consumption. Application five uses a cellphone screen to visualize the data. However, this cellphone is connected to sensors, and so it can also be considered as gadget. Finally, application six is a gadget placed close to the location of the water consumption. It visualizes the water consumption by changing the colors of a light emitter, or by showing numerical data describing the water consumption.

To summarize, the technology used at the first two levels is more ambient and uses presentation techniques embedded in the environment, while the technology selections done in stages three and above are more traditional, and usually involved personal computers and cellphones. However, there were three applications (5, 6 and 7) targeting levels three and above, that used ambient technology, such as different kinds of artifacts placed in various locations in a house for people to check them when they pass by [13, 23, 25].

Summary of findings

This section presents the results summary table (Table 3). The table presents the TTM stages, the context of use, the display technology used, and the relevant IT artifacts.

TTM stages	Context of technology usage	Technology implemented	Relevant studies
1	Public	Public displays Decorative displays	9, 11 5, 6,7
2	Public	Public displays Decorative displays	9, 11 5, 6, 7
3	Private Semi-public	Personal computers Cellphones Decorative displays	1, 2, 3, 4, 10 3, 4, 8 5, 6, 7
4	Private Semi-public	Personal computers Cellphones Decorative displays	1, 2, 3, 4, 10 3, 4, 8 5, 6, 7
5	Private Semi-public	Personal computers Cellphones Decorative displays	1, 2, 3, 4, 10 3, 4, 8 5, 6, 7
6	Private Semi-public	Personal computers Cellphones Decorative displays	1, 4, 10 4, 8 5, 6, 7,

Table 3: TTM stages and the corresponded places and technology used

The applications categorized in the first two TTM stages use public displays. Artifacts 5 and 6 were placed in a semi-public environment and they support the users' behavior change, where users are the owners of the artifact and at different stages than the 1 and 2. Even if stages 1 and 2 are not the primary target of artifacts 5 and 6, these artifacts can influence people who are at these first stages if the artifacts and the people share the same semi-public place. The rest of the IT artifacts previously categorized in stage 2 have been discarded for this stage since they need to be actively used if they are to influence the behavior of an individual. However, people who are in stage 2 have not yet taken any action, thus these applications are not actively used in stage 2.

At TTM stages 3, 4, and 5, personal computers, cellphones and decorative displays are used in private and semi-private places. The relevant artifacts are placed next to the corresponding technology in Table 3. Some of the applications have been tested in cellphones and computers.

Finally, TTM stage 6 uses the same technology and places as the previous three stages, but the relevant IT artifacts are different. At this stage people made the new behavior a habit. They use technology to keep track of or to increase their performance. Application 1 is categorized at stage 6 because users mentioned that the application made them reflected on their actions, so they tried to take new actions be more physically active than before.

About Social Comparison

The motivation for this paper was to examine the design space of features using social comparison in behavior change support. Seven of the twelve studies (1, 2, 3, 5, 7, 10A and 10B) specifically examine the effect of visualization of other people's data in behavior. The rest of the applications (4, 6, 8, 9 and 11) adopted the techniques of social influence or social comparison, but did not specifically study its effect on behavior.

The papers presented mixed findings of the effectiveness of social comparison for behavior change. Papers related to applications 1 and 3 concluded that features based on social data did not influence behavior change. However, the analysis of application 1 also shows that social comparisons were observed during the evaluation as individuals discussed, compared and reflected on their progress. These discussions were triggered by visualizations of social data. In the paper analyzing application 3, the results show that people who were assigned to teams did worse compared with the users who were using the same application without the social features designed for teams. The studies discussing applications 2, 5 and 10 concluded that the visualization of other people's data given to an individual had a significant positive impact on the individual's progress towards the new desirable behavior. The studies analyzing applications 2 and 7 point out that the reference of a comparison is an important aspect of social comparison. Users of application 7 wanted to be compared with users who were similar. For example, a family of four did not want to compare their water consumption with a family of two. In the paper presenting application 9, it was found out that when people compared their results with their neighborhood and different neighborhoods, they expressed feelings of increased awareness and started to analyze why their behavior differed from their reference group's behavior.

The findings of studies discussing applications 2, 5, 9, 10A, and 10B show that the visualization of other people's data in direct comparison with the individual's personal data has a positive impact on behavior change. There were only two

studies related to applications 1 and 3 that concluded that visualization of other people's data has no effect in the behavior change process. Moreover, the papers that analyzed applications designed to support people for TTM stages two and below showed a positive effect of the visualizations that use social comparison. Even though the sample size for applications specifically targeted for TTM stages one and two is small, application 9 could clearly illustrate the potential of a social comparison for these TTM stages through the analysis of subjective user comments.

Health Related Artifacts and Eco-Related Artifacts

From the eleven applications discussed in this paper three focused on behavior change towards a healthier lifestyle (applications 1, 3, 5), while six focused on behavior change towards an eco-friendlier lifestyle (applications 4, 6, 7, 8, 9, 10). The eco-applications seemed to have a variety of technology usage, for example, public screens/projections (applications 8, 9), computer/mobile applications (applications 4, 8, 10) and different gadgets (applications 6, 7), while the health-focused applications used mainly computer/mobile applications (1, 3) and one of them used a gadget (5). The eco-applications covered all TTM's stages, while applications targeted at health behavior change were designed mainly for TTM stages three and above.

CONCLUSIONS

This paper analyzed previous research on "where", meaning the context of use; and "when", meaning the timing of use as part of the behavior change process; information technology can effectively support behavior change through social comparison. The main contribution of this paper is the categorization of the applications using social comparison features into TTM stages and their context of use. Thus, we presented the role of social features in different use contexts and behavior change stages. This information can be used by designers of behavior change applications to target specific user groups. More explicitly our finding are the following:

- The visualizations of social data placed in public usage contexts are most suitable for the first two TTM stages. At these stages, social features typically target promoting awareness.
- The visualizations of social data suitable for the three middle TTM stages are most effective when used in semi-public and private contexts, such as with personal computers, cellphones and various gadgets. At these stages, users need personalization and privacy, which can be achieved through personal devices, and devices that support interaction within groups.
- The visualizations of social data targeted for the last TTM stage is placed in semi-public and private use contexts, which seamlessly integrates with user's daily activities and environment. At this stage, visualizations have a role in sustaining the acquired new behavior.

Research on behavior change support technology has focused on design techniques and strategies for targeted interventions. This paper examined the design of such technological applications through two parameters, context of use and timing, and one design feature, the visualization of social data. The findings show that at different stages of the behavior change process, different usage contexts are appropriate. In future research, we will explore different ways to visualize the relation between other people's data and that of an individual to achieve behavior change.

ACKNOWLEDGMENTS

This publication has received funding from the European Union's Horizon 2020 research and innovation programme – the Marie Sklodowska-Curie Actions grant agreement no. 676201 - CHESS - Connected Health Early Stage Researcher Support System. We also thank all the people who have supported us, in work and private environment, to complete this paper.

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