Informed Choices, Progress Monitoring and Comparison with Peers: Features to Support the Autonomy, Competence and Relatedness Needs, as Suggested by the Self-Determination Theory

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ABSTRACT

The use of fitness apps (some based on behavior change theories) is increasing. Recently a taxonomy mapped app features to the Basic Psychological Needs (BPNs) posited by the Self-Determination Theory (SDT), providing the opportunity to inform the design of fitness apps by this theory of human motivation. However, it is unknown if the user's perceptions of such SDT-based design would support the BPNs. This is important as the SDT states that interventions supporting the BPNs produce long-term benefits. Following the taxonomy of app features based on SDT, we designed and developed Agon, an iPhone app. We deployed the app through a one-month field study involving 49 participants. The study allowed participants to use the app in their everyday lives, providing sufficient exposure for us to capture meaningful perceptions. This work contributes empirical evidence that the features included in our design correctly mapped to the Basic Psychological Needs. We discuss implications for researchers and designers targeting effective interventions.

CCS CONCEPTS

• **Human-centered computing → HCI design and evaluation methods**.

KEYWORDS

Behavior Change; Fitness Trackers; Human Motivation; mHealth; Step Counter

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1 INTRODUCTION

Many people around the world use apps on their smartphones (e.g., MyFitnessPal [63], Endonomdo [20]) to monitor their physical exercises and improve their level of physical activity. Recent representative surveys show that over 100k smartphone health apps available worldwide, and 500M users use mobile health applications to keep track of their everyday activities [19, 26]. In this paper, we refer to this group of applications as *behavior change apps*, as these have been explicitly designed *to foster and assist behavior change and sustainment* [34, p. 3308]. Behavior change apps incorporate various features to modify users' behavior, many of which are used simultaneously (e.g., goal-setting, performance sharing, reminders).

Recently, researchers started to question the usefulness and efficacy of some of these apps [11, 24, 35, 56], and call for further exploration in the area, for example, looking at the optimal number and combination of app features [55].

Given that commercial apps, in most cases, incorporate multiple features, they are often unsuited for controlled experiments as it remains challenging to identify the effects of the individual features on one's behavior. This identification would be necessary to design more effective and efficient behavior change apps.

Furthermore, prior research has not extensively explored users' perceptions of behavior-change apps on a minimal set of behavior change features based on established behavioral change theories. Users' perceptions can be seen as good predictors of engagement, motivation and well-being [52, p.20,p.213] [47]. Therefore, capturing and understanding the users' perception can offer researchers valuable insights into how technological features might influence users' behavior. This marks a salient motivation of our work.

In this study, we design, develop, and deploy Agon, a step-counter app for smartphones. This app's design is grounded on the Self-Determination Theory (SDT), a human motivation theory that focuses on the types and sources of motivation that impact behavior. The SDT has been successfully applied across multiple life domains (e.g., see [16] for a review). The theory posits that human beings have three basic psychological needs (BPNs): autonomy, competence, and relatedness (we will define them in the next section). Furthermore, the theory states that the satisfaction of the BPNs is a requirement for optimal development, integrity, and well-being [52, p.242]. Recently a taxonomy [66] mapped app features to these BPNs, providing a tool for designers to evaluate how app features may motivate individuals towards their goals.

As a first attempt to design SDT-informed app features, we build on this taxonomy and create Agon. This app incorporates three distinctive features: (1) goal setting to support *autonomy*; (2) history to support *competence*; and (3) peers comparison (in the form of step-counts) to support *relatedness*. We hypothesized that in a longitudinal deployment, participants would perceive support to the BPNs and feel motivated towards the target activity (i.e., walking or running). We then formulated the following research question:

RQ: What are the individuals' perceptions about the hypothesized app features that aim to support autonomy, competence, and relatedness when it comes to improving their physical activity?

We conducted a field study of the app that spanned 4 weeks to address this research question. We recruited 49 participants for the study. We asked our participants to fill a diary documenting positive and negative experiences. Subsequently, we invited 15 of them to a follow-up contextual interview to better understand their experience with the app and their reflections. Our results indicated that: participants experienced feelings of being autonomous when setting a step goal; also the use of the app provoked participants reflections, self-evaluations, and contemplation of their physical activity routines; finally, the design of the relatedness feature elicit feelings of companionship, comparison, and competition, but not feelings of being connected to each other, as we initially expected.

We contribute a novel design of a fitness app derived directly from the app features' taxonomy based on the SDT. This app was intentionally designed to support *autonomy*, *competence*, and *relatedness* towards the goal of improving the individuals' physical activity levels. This study also contributes qualitative empirical evidence of the users' perceptions of how the app supported their BPNs. We support app designers with suggestions on how to improve the design of features that aim to support the BPNs.

2 BACKGROUND AND RELATED WORK

Our work lies at the intersection of two principal research areas: (i) a contemporary theory of motivation (i.e., Self-Determination Theory) and (ii) empirical research in HCI on designing behavior change app features to support physical activity.

2.1 Self-Determination Theory

The SDT posits that people have different *levels* or *amounts* of motivation to perform a specific activity. It also states that people have different types of *orientation of motivation* i.e. the underlying attitudes, goals and values that give rise to action [15]. These types are classified as *intrinsic* and *extrinsic* motivation. Intrinsic motivation refers to doing an activity because the person finds it inherently interesting or enjoyable (e.g., reading a book). Extrinsic motivation refers to doing an activity because it leads to a separate outcome (e.g., preparing for an exam). Therefore, different types of motivation differ in the sources that initiate them, in magnitude, in affects, and in the experiences of the individual and their behavioral consequences [52, p. 14].

Moreover, intrinsically motivated behaviors are autonomous and experienced as being volitional. In contrast, extrinsically motivated behaviors can *vary widely in the degree to which they are controlled versus autonomous* [50]. For example, a student may be extrinsically motivated to study for an exam to avoid the punishment of parents but also could be motivated because they observe a valued outcome (i.e., getting a degree).

More specifically, the SDT affirms that the extrinsic motivation can be *internalized* and that the degree of internalization demonstrates the degree to which the behavioral regulation is relatively autonomous versus controlled [52, p. 14]. Consequently, the SDT introduces a *control–autonomy continuum* to explain this internalization process. It spans from *amotivation* (or absence of intention to act) to *external regulation* (to obtain a reward) to *introjected regulation* (to avoid guilt) to *identification* (accepted external regulation) to *integration* (self-determined action).

Additionally, the SDT explains that these –previously mentioned– extrinsic motivation types can urge a person to behave a certain way in the short-term but will fail to maintain the behavior over more extended periods [15]. As a result, behavior-change interventions designed for extrinsic motivation types may not sustain the new behavior after the intervention ends.

Mainly, the theory describes three Basic Psychological Needs (or BPN), that when satisfied by the contextual conditions, leads to a self-determined action.

In this work, we adopt the following definitions for each BPNs:

(1) *Autonomy* "refers to feeling willingness and volition with respect to one's behavior. The need for autonomy describes the need of individuals to experience self-endorsement and ownership of their actions." [52, p. 86]
(2) *Competence* "refers to feeling effective in one's interactions with the social environment–that is, experiencing opportunities and support for the exercise, expansion, and expression of an individual's capacities and talents." [52, p. 86]
(3) *Relatedness* "refers to both experiencing others as responsive and sensitive and being able to be responsive and sensitive to them–that is, feeling connected and involved with others and having a sense of belonging." [52, p. 86]

In our work, we set to understand how the BPNs constructs could inform the design of a mobile app to support physical activity and, subsequently, elicit the users' perceptions of them.

2.2 Behavior Change App Features

2.2.1 Goal-Setting. Researchers have created various implementations of goal-setting features in smartphone apps. For example, Consolvo et al.[8] devised and field-tested an interactive prototype for mobile devices where the step goal was determined based on 1-week data of previously recorded users' step activity. Subsequently, they [10] developed yet another mobile phone prototype, which offers participants to specify their physical activity goals by themselves. Later, Munson et al. [42] experimented with a physical activity mobile app where users selected predefined categories in which their weekly physical activity goals fit best. More recently, Gouveia et al. [28], developed HABITO, a step-tracking app, which defines two goal-setting mechanisms: one in which users established the daily distance they want to walk and a second one in which the app offered a default walking distance. Hartzler et al. [33] developed NUTRIWALKING, an app, which offered personalized daily exercise goals. Their goal-setting feature suggested options with exercise duration, based on participants' self-reported baseline level of physical activity.

Finally, other previous research efforts identified the components of appropriate goal-setting strategies to support physical activity. They suggest tailoring the goal difficulty to the user's ability level and re-evaluating the goals based on achievements to increase the qualities of the goal-setting functionality [3]. In sum, this research strand focused on a technological mechanism to self-set goals by selecting from a list of options or inputting the objective directly. In light of this prior research, our work explores how providing participants with information about their physical activity (e.g., previous week's daily average step-counts) and suggesting goals based on their performance can help them make an informed decision concerning their goals.

2.2.2 Progress Monitoring. Researchers followed different approaches to communicate app users their activity progress. For example, in their UBIFIT system, Consolvo et al. [10] used a garden metaphor that blooms throughout the week as users conduct their physical activities. Harries et. al [31] presented a step-tracking mobile phone app where participants could see their total daily steps (in a numerical form and in the form of line graphs to overview weekly step progress) after a running workout. Their participants also had the option of viewing step data for the previous day, past week, and their history. Munson et al. [42] explored various progress visualizations: included bar and line charts with completion percentages of the user's goals. Sankaran et al. [54] developed a specific app for cardiac tele-rehabiliatation: the participants monitored their progress on a horizontal progress bar with an animated person running towards the goal. Oyibo et al. [44] in their BEN'FIT system adopted a horizontal bar to show the users' weekly physical activity levels. In sum, this research strand focused on the use of visual elements or graphs to communicate activity progress to its users. We aim to extend this research by investigating how a text-based list of steps counts with a temporal component can help participants relate their activity performance with their day-to-day activities.

2.2.3 Peers Comparison. Several prior research efforts developed interactive prototypes to encourage physical activity, exploiting various social support strategies and techniques. One of them is Houston [8], a mobile application that shares step-counts with friends in the form of achieved activity levels and progress towards the goal. Its field deployment suggested that the participants felt social pressure to achieve a given objective since they did not want to be the last in a leader-board list or wanted to perform better than a friend from the list. Colusso et al. [7] studied the concept of closeness to comparison in the context of a video game, where participants compared their scores (using bar graphs) to the one they compete with. Hartzler et al. [33] in their NUTRIWALKING app incorporated an exercise feature with teams of 10 members, a digital "coach", and free-form interaction through team posts and private peer-to-peer messaging. Altmeyer et al. [2] presented a gamified system consisting of a physical activity tracker, a mobile application, and a publicly-accessible (web) application. They demonstrated that social sharing of personal step counts increased the overall number of steps for an individual, arguing that the public disclosure increased the participants' level of responsibility. In sum, this strand of the research focused on reflective strategies to mindfully motivate people to exercise more, and confirmed that sharing physical activity-related details with peers not only contributes to the overall user experience and enjoyment of workouts (e.g., [42, 69]) but can also be a powerful motivator for health activities at large (e.g., [21, 62]).

Collectively, prior research endeavors were not necessarily grounded to a motivational theory to create behavior change mobile applications and evaluate users' motivation and attitude towards physical activity (e.g., [40]). Whereas our work specifically adopts the SDT to develop a mobile application (to facilitate an increase in physical activity) and explore the users' perceptions on supporting features for the BPNs: autonomy, competence, and relatedness. This marks the novelty of our contribution.

3 RESEARCH PROTOTYPE

3.1 Design Process and Rationale

Our goal was to design a steps-tracking app with a minimal set of functionalities that support the BPNs as posited by the SDT. We started the design process by studying the examples of apps and the characteristics of the features presented in the taxonomy of behavior change apps features based on SDT [66]. Then, we filtered by high coverage of taxonomy features and picked the top 2 of each BPNs (we did not limit our choice to one feature to avoid any bias or prejudice towards any feature). Then, we discarded from this selection: *Reminders* as it uses an overcrowded communication channel; and *Performance Sharing* as its implementation may disclose the participants' identity. Finally, the selected feature-set was: *Goal Setting*, *Activity Feedback*, *History*, and *Peers Comparison*. Next, we used these categories as the foundation for our design process, which we describe in the following paragraphs.

3.1.1 Initial Approach. We considered the *Goal Setting* taxonomy category as the foundation of AGON's *autonomy* support feature. This category describes apps that prompt the user directly with their goals [66]. In our approach, AGON calculates the user's daily average steps using past logs. Then, it displays this information to the user and suggests a percentage increase of this daily average. The user can accept or deny this proposition (see Figure 1a). We considered this design might support *autonomy* because it provides information to the user, suggests a concrete goal, and provides an option to accept or refuse this new goal.

Our second feature attempt to support *autonomy* allowed the user to choose between participating in a weekly group steps competition or working towards their weekly step goal individually (see Figure 1b). We considered this design might support *autonomy*, because it allows the user to express their will concerning the method that will lead them to their step-goal.

We considered the *History* and *Feedback* taxonomy categories as the foundations of AGON's *competence* support feature. The former

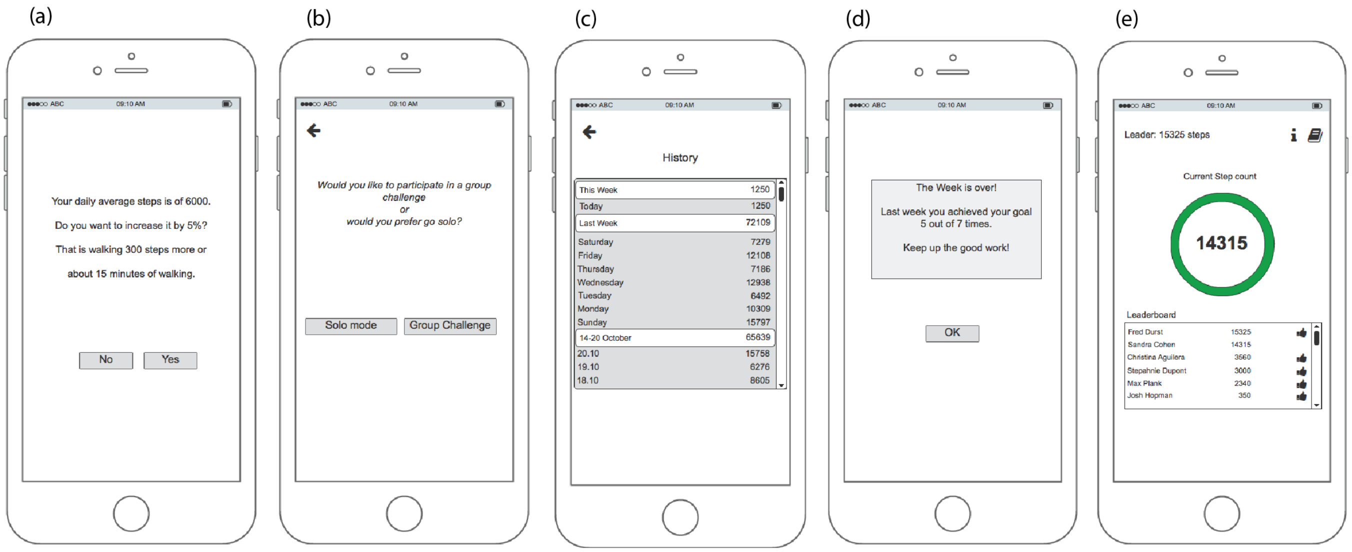

Figure 1: (a) Goal setting feature with options to accept or deny the proposition. (b) Goal setting feature to choose weekly group steps competition. (c) History feature: Each row shows the pair date-steps counts. The list is ordered from most recent to oldest. (d) Weekly pop-up message with activity feedback. (e) Peers Comparison showing a list of participants with their total step-counts; at the end of each row a thumbs-up button to provide feedback to other participants.

presents the user with a representation of their activity over a time period, and the latter provides the user with information about how the task was performed in a given session [66]. Initially, we thought of having a *history* of step-counts including daily-step totals and corresponding dates (see Figure 1c). We considered this design might support *competence* because it allows users to reflect on their step-counts and feel effective about their walking activity levels. We thought of using *feedback* as a second way to support *competence* by displaying a pop-up message with weekly activity performance results (see Figure 1d). Similarly to the *history* of step-counts, this design allows users to feel effective while doing the walking activity. We must note that the individual's sense of effectiveness will depend on the actual activity performance (e.g., little steps lead to bad performance and consequently bad effectiveness, and vice versa).

We considered the *Peers Comparison* taxonomy category as the foundation of Agon's *relatedness* support feature. This category presents an ordered list of scores and people who perform the same activity [66]. Therefore, we thought of designing a *peers comparison list* including a list of users names with weekly steps-totals (see Figure 1e). As a second way to support relatedness, we thought about how users could encourage other competitors by tapping on a thumbs-up icon next to each competitor's name. This design allows users to feel connected and important to each other by knowing that they are taking part in the same activity and by having the chance of supporting themselves through the thumbs-up action.

3.1.2 Refined Approach. In this phase, we performed an expert evaluation of the initial app design, which consisted of reviewing the design and interaction of each app feature from the lens of the Self-Determination Theory. For this activity, we involved five researchers from our institution, all familiar with the SDT, to study a detailed design document and UI maps. Notably, we asked the experts to evaluate whether the app's features provided support to the BPNs posited by the SDT. Further, we asked experts to perform a Heuristic Evaluation of the design [41], to iron out usability issues. The feedback we collected in this phase allowed us to update the design of Agon in the following ways: first, for the *autonomy* feature, we kept the design where the app showed the daily steps average, with the option to increase this average or not. We discarded the design that allowed users to choose a group or individual competition, because leaving this option would make the relatedness feature (peers comparison) optional, which was not our intent. Instead, we thought of removing this choice and leaving the group competition (represented by the peers comparison) as a fix app feature.

Next, for the *competence* feature, we kept the history design, which provided more information to satisfy the sense of effectiveness while walking or running. We preferred this design on top of the pop-up message because we could guarantee a longer exposure to the history that remains accessible in the app all the time versus the pop-up message that appears on the screen a limited time (i.e., couple of seconds once a week). Finally, for the *relatedness* feature, we kept the peers comparison (as we mentioned earlier) but removed the thumbs-up because we considered it a double support for the *relatedness* need.

3.1.3 Final Approach. Once we completed the refined version of the designs and the UI-map, we developed Agon. This app implements three features based on each of the BPNs: (1) goal-setting to support *autonomy*; (2) steps-history to support *competence*; and (3) peers comparison to incorporate *relatedness*. Agon differs from other commercial apps in the following ways. First, unlike many

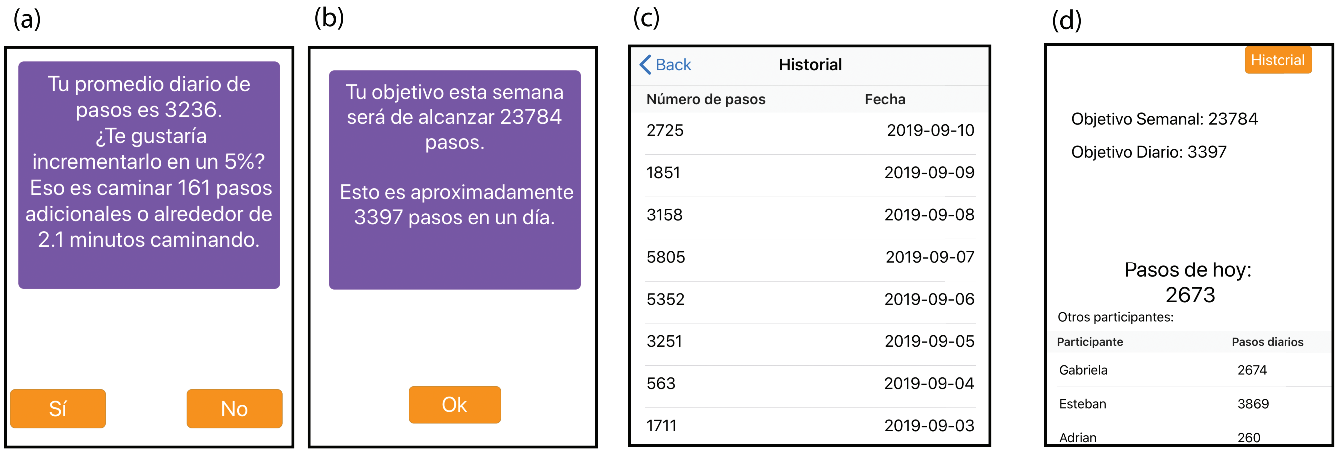

Figure 2: (a) Goal-setting feature (first dialogue): *"Your daily step goal is 3236 steps. Would you like to increase it by 5%?. That is walking 161 additional steps or about 2.1 minutes walking."* (b) Goal setting feature (second dialogue): *Your weekly goal will be to reach 23784. This is approximately 3397 steps per day.* (c) History feature: Each row shows the pair steps counts-date. The list is ordered from most recent to oldest. (d) Main Dashboard Screen: Displays the history button on top-right; below the weekly and daily step goals; below the daily step-counter; at the bottom the peers comparison feature.

commercial apps and services, it is developed upon an established behavior change theory in mind. Second, Agon was purposefully designed with a minimal set of features to research the distinct effects these group of features has on the users' behavior. In the following paragraphs, we detailed the rationale and the relation to the SDT that lead to our final design.

We designed the *goal-setting* feature to support the basic psychological need of *autonomy*. We hypothesized that a *goal-setting-autonomy-support* feature could be represented by a dialogue-box displaying personal information to the users. This information helps users in the goal-setting-decision-making process by informing them of their previous week step-count average and proposing to walk a higher number of steps the following week (see Figure 2a). In the same dialogue-box users can see the equivalent number of steps for this increase and the approximate amount of time it would take to walk those steps (e.g., *"Your daily step goal is 2936. Would you like to increase it by 5%? That is to walk 146 additional steps or about 1.9 minutes walking."*)[1]. Below the dialogue box and on the left side, we placed a *yes* button (to accept the step increase) and on the right side a *no* button (to reject the step increase and continue targeting the same average number of steps from their previous week). After the user taps on any of the two buttons, the text in the dialogue box updates to present a sentence indicating the weekly objective and the approximate daily steps (see Figure 2b). In the next lines, we relate this feature design to the SDT literature.

According to the SDT, by offering users information (i.e., their average number of steps counts) about a decision they need to make (i.e., defining weekly step-goal), they can take an informed choice and thus feel autonomous when specifying their weekly step-goal [52, p. 461]. Also, the action of goal-setting contributes to an *internal perceived locus of causality* (or I-PLOC)[12]. In concrete, an intentional behavior can be either internally motivated (i.e., intrinsic motivation) or externally motivated (i.e., extrinsic motivation). For instance, researchers found that students' learning outcomes increased when teachers provided them options and choices in a learning environment [17, 45]. The SDT states that when a goal is imposed by someone else (or by an app), it will undermine autonomy and reduce the person's motivation to perform the activity. On the other side, a self-imposed goal would contribute to the basic need of autonomy and supports autonomous motivation to perform the target activity (cf. [14, 51, 53]).

We designed the *steps-history* feature to support the basic psychological need of *competence*. The *steps-history* feature is a simplified version of related functionalities adapted from FitBit [25] and Steps App [59]; it can be accessed from the Agon's main screen by tapping on top-right button. We designed this feature to allow users to see the progress in steps they have made through time. Therefore, Agon displays two columns one indicates the steps counts, and the other shows the date when those steps were taken (see Figure 2c). This feature differs from an *activity feedback* feature, which provides statistics, scores, or other information on the user's performance. We offered users to examine their collected data for one year back. Showing past steps allows the users to reflect on the temporal component of the walking activity. Looking at the events from specific days, users can relate success or failures to meet the steps-goal to environmental factors that might have influenced their activity (e.g., peaks of stress, work deadlines, menstrual cycles, family problems). By contrasting this information, users know how their circumstances might influence the walking behavior, therefore supporting the basic need of *competence*. According to the SDT, receiving information that is useful and allowing individuals to learn and improve contributes to the support of their *competence* BPNs [49].

[1] The recommendation for the weekly physical increase is no more than 10% [64]

We designed the *peers comparison* feature to support the basic psychological need of *relatedness*. This feature was in parts motivated by the leader boards from Strava [60] and Freeletics [27], both renowned fitness apps. The *peers comparison* can be observed from the Agon's main screen, right below the daily step counter label (see Figure 2d). We designed this feature by creating a two-column list. The left column displays participants' names, and the right column participants' daily steps sum. In this way, users can compare their performance with other participants who participate in the same activity over time. However, in contrast to Strava and Freeletics, we adopted a privacy by design approach [5] and partially anonymized the participants' data by displaying only their first name and step counts. Besides, the *step-counts feature for peers* does not include either icons or profile images of the participants. The actual step-counts data was gathered from the Apple's HealthKit app database for which participants granted access after installing the Agon app. Through a peer comparison, users can evaluate the impact of their actions (i.e., walking daily) on others and feel more effective and related to other participants [23], supporting the *relatedness* BPN. We now discuss our research methodology.

4 METHODOLOGY

Our methodology was inspired by research from Peng et al. [46]. These authors studied smartphone owners' perceptions of mobile health apps by conducting interviews and identifying themes. Given our study's object, namely behavior change apps for fitness, we opted for a field study spanning 4 weeks as we deemed users would require weeks to adjust to the new routines and reflect on their experience.

4.1 Participants and Recruitment

The participants sample included 49 students, age ranged from 18 to 30 years ($M = 22.2, SD = 3.1$). Of these participants, 30 were women (61.2%). Participants were compensated with the equivalent of 25 USD for their participation, regardless if they completed the study. We captured demographic data (i.e., name, gender, age) through a screener that also served to check whether respondents qualified for the study. We recruited participants through flyers placed on the university campus and social media sites. The flyers contained a basic explanation of the study and an email address to write to sign up. If they replied to the study call, the first author, acting as a recruiter, contacted them to screen them over the phone. If they qualified, the recruiter provided instructions on how to download and install the app and the following steps of the research.

We excluded participants who: (1) were younger than 18 years old (as we did not have resources to collect approval from the legal guardians or parents of minors); (2) did not possess an iPhone 5 or newer model (given that our technological intervention was developed exclusively for iPhone); (3) expected to not have Internet access for more than 7 consecutive days during the study; (4) could foresee instances in which they would be unable to undertake physical activity for more than 7 consecutive days; participants needed to be able to use the app for at least a week to guarantee they were exposed to the app features. Seventy-seven individuals replied to the study call. The first author contacted them to schedule a phone screen. Of 77, 8 did not answer the invitation email. The screening of the remaining 69 individuals for participation in the study found that 12 did not qualify for the study for one of these reasons: (1) they did not have an iPhone 5 or newer (7 respondents); (2) did not reach the end of the screener (5 respondents). Therefore, 57 participants began the study, and during the 1-month deployment we registered 8 dropouts. The final number of participants of the study was N=49.[2] We informed participants that their involvement was voluntary, that they could withdraw from the study at any time, and that anonymity was guaranteed. The Ethics in Research Committee of our university approved the research protocol.

4.2 Study Procedure

We conducted a 1-month field study in a mid-size city in Central America. This period allowed participants –considering Agon minimal set of features– to be exposed, understand, and react to the three app features (*goal-setting*, *history*, and *peers comparison*). Our study consisted of three phases.

4.2.1 Phase 1: On boarding and Setup. Participants signed the consent form online and received setup instructions onto their emails (i.e., download the research app from Apple App Store, grant access to their HealthKit data, carry their phones, and use the app for four weeks). This phase lasted 4 days to give participants enough time to follow the setup instructions.

4.2.2 Phase 2: Interacting with Agon app. In this phase, we collected participants' step-counts. Every Monday, the app suggested a weekly and daily step goal, based on the steps average from the previous week. If the app did not obtain steps from the previous week, stemming from the prior research [37], it suggested 5K steps or approximately 30 minutes of walking each day to start with. Participants had to complete a diary through a different online platform by the end of the day. It aimed to record users' perceptions about Agon app.

4.2.3 Phase 3: Interview. At the end of the four weeks, we invited 15 participants to an interview session based on the frequency of use of Agon as reported in their diary entries. We did this because we aimed to collect reflections and reactions on the app from active and inactive participants. More specifically, we recruited 9 "power users" (i.e., who used the app every day) and 6 participants who were not particularly active with the app, as expressed in their diary entries. Collecting insight perceptions from active participants allowed us to understand better the app feature characteristics that made participants feel more engaged with the app. Similarly, by interviewing participants who interacted little with Agon, we captured their perceptions concerning the disengagement they had towards the app. Engagement is relevant in application-mediated studies where participants must be exposed to the mobile system's characteristics and functionalities to capture meaningful insights. For the semi-structured interviews, we designed an interview's script unpacking our *RQ*, aiming to elicit the participants' perceptions of the app's supporting features regarding their physical activity. The first two authors conducted the interviews.

[2]See the flowchart describing the recruitment process in the supplementary material: https://osf.io/rb43c/?view_only=a7c5a118b235410abed4495b5aa91ab6.

The interview protocol [3] was as follows: We explained the purpose of the interview (2 minutes). We followed the interview script to capture their perceptions about the AGON app features. We inquired about their motivation to use the app and suggestions to improve it (25-40 minutes). While one author conducted the interview, the other served as a note-taker. We used a voice recorder to capture the interviews. Our dataset consists of 6 hours and 46 minutes of interview records. Finally, to aid the data analysis, we transcribed the recordings verbatim. The interviews were conducted in Spanish, the native language of the participants, and the two researchers who performed the interviews.

4.3 Data Analysis

Our data analysis drew from two sources of insights: the participants' diary entries which covered all 49 participants, and the semi-structured interviews conducted with a sub-sample of 15 participants. We conducted data analysis in Spanish. At the end of the analysis, the quotes taken directly from the data were translated from Spanish to English (by the first author, a native Spanish speaker) to keep the meaning as close as possible to the original.

At the inception, two researchers engaged in an affinity diagram process to analyze the interviews [4, 32]. This method is used to organize large amounts of unstructured qualitative data, such as participants' interviews, and has been extensively applied in HCI studies [22, 30, 36, 38, 68]. As the first step, two researchers created post-it notes independently from each other. These notes were distilled from the audio recordings of the 15 interviews and diary entries. The notes included comments, ideas, or quotes that caught the researchers' attention. Then, each researcher placed their notes on a separate wall to read the notes of each other.

Next, we spend approximately 8 hours conceptualizing categories and subcategories in an iterative, interpretative and synthesized analysis process. We cluster the post-it notes by their semantic affinity (common patterns) and aligned them with the research question. We repeated this process until we reached a consensus on the categories. To ensure the result's methodological accuracy, we used a triangulation strategy [61], where two researchers with different points of view analyzed the data (inter-subjective). As a result, in about 4 hours, we compiled a document with the categories (i.e., themes) and representative quotes from our participants. We also held meetings with researchers outside of the project to challenge our assumptions and corroborate the themes.

Next, we present the main themes or categories we identified from our data corpus analysis and support them with quotes from the participants. The identified themes are not orthogonal; they describe interesting characterizations of our participants' experiences with AGON app. In the remainder of the paper, we use pseudonyms to describe study participants.

5 FINDINGS

Our study reveals that the goal-setting feature supported the need for *autonomy* because participants perceived the decision to set the step goal their own. This feature also contributed to motivating participants to achieve the goal. The steps-history supported the need for *competence* because participants reflected on their step progress through time. The step-counts for peers feature partially supported the need for *relatedness* because participants reported feelings of companionship, curiosity, and at times competitiveness against self and the others, but not feelings of being connected to others.

5.1 Autonomy Support Feature

Drawing on the perceptions and the use of the *autonomy* support feature, we identified two empirical categories from our data corpus. Namely, (1) the perception of setting a goal increment; and (2) the emotions experienced through maintaining an individual steps goal.

5.1.1 Perception of step goal. Every Monday, AGON app proposed a step goal to participants. Gigi, 26 emphasized the value of having a choice on the number of steps the app suggested to increase: *"I felt control when accepting or denying [this recommendation]. I was the one deciding if I wanted [it] or not. However, in a sense, [the app] was imposing me the number, but because I could at least say if I wanted to go for that number or not, I had somewhat decision power."* Giss, 30 offered a similar perception: *"I like to have control of my daily and long term step goals."* Similarly, Lily, 20 expressed her feeling of choice when deciding on her step goal: *"I feel I was deciding [on the number of steps], and it was my own amount. I never felt pushed to walk."*. Also, Faby, 20 explained how he decided not to increase the daily goal: *"This number is too much and I can't. When I realized I couldn't make it I told the app I can't increase 5%"*

Besides, participants perceived the step goal as a form of personalized goal they were striving to meet by the end of the week. For example, Gigi discussed: *"The app adjusted the step goal. If I walked less steps during the week, it didn't tell me: "This was last week's goal, now you need to do more", instead it adjusted the goal to myself."*. Furthermore, Mar, 22 commented on a realistic, achievable step goal AGON app set for her: *"I like [that] the app suggests a more realistic step goal based on the previous week steps average."*. Mary, 19 added to that endorsing privacy-aware architecture of the app: *"I appreciated [that] the app used the data that was stored in my phone's database and used it to calculate a reasonable increase in my step counts."*

5.1.2 Emotional spectrum of step goal perceptions. This category relates to the feelings evoked by our participants when attempting to maintain a daily step goal. Feelings varied between positive affect, interest in the activity, and feelings of challenge. For example, Addy, 20 expressed her feeling of contentment produced by having a step goal: *"I feel very well, because I have a daily step goal, it pushes me to try to reach it."* Anny, 21, when speaking about the step goal feature elaborated on her personal experience with AGON app: *"I felt interested, because [the app] shows you the weekly step goal and at the same time the number of steps I should do every day to achieve it."* Setting a daily step goal pushed our participants to take actions to reach it, for example, Gigi, 26 explained: *"The weekly step goal motivated me to do more than what I was [usually] doing.*

Some other participants felt they were participating in a challenge, which motivated them to initiate physical activities. For example, while reflecting on using the app Cara, 22 said: *"Even though I did not walk much, I feel it is an internal competition like a*

[3] See the interview protocol on OSF: https://osf.io/rb43c/?view_only=ef24559418df4b948872dc357f200e08

challenge." The feeling of effort was also commonly expressed from our participants, Gigi elaborated: *"I try to use the stairs more instead of the elevator and to park my car further away so that I can register more steps. It would be good if we receive an alert when the day is about to end and we have not reached our step goal."*

Collectively, these reflections help illustrate how AGON app provoked feelings of being in control of the step goal. Also, customized manageable step-goal increments helped participants to observe the steps-objective as something reachable. Additionally, it encouraged participants to engage in more physical activities autonomously.

5.2 Competence Support Feature

The perception and the use of the *competence* support feature turned participants to focus on their self as well as made them reflect on their own performance and improvement while engaging in physical activity. From our data corpus, we identified the following three categories: (1) reflections on self-evaluation; (2) the feelings of empowerment; and (3) the sensations produced by acknowledging past performance.

5.2.1 Self-Evaluation. By self-evaluating their activity, participants could monitor their progress and reflect on their own physical activity Nicky, 19 explained: *"The purpose of the history is to compare how the step counts were at the beginning and at the end of the week."* Kary, 22 speaking about her self-reflection process, restated its value to motivate her to make an extra effort in her workout routine: *"With the history I could see if I have made some progress, if I make some effort and see the improvement, then it motivates me to exercise more."* Kary also discussed the emphasis on self-improvement as an integral part of sport and activity tracking apps, and opened up a discussion about the lack of its support. This was corroborated in the following statement: *"This history [feature] is a personal retrospective, that allows me to see the progress or regression in my exercise pattern."*. Sammy, 18 reflected on how the app made him re-think the importance of doing physical activity. He explained: *"Today I feel well using the app, it is very monotonous but good and useful. Besides, I truly felt it had pushed me to walk more. These last days, doing physical activity became something that took my mind over the course of a month. This made my life change and became a little more active. I often chose walking instead of taking the bus, and I think that's what it is about, about little changes."*.

5.2.2 Empowerment. A feeling of empowerment was felt by some of the participants, which encouraged them to have greater confidence in themselves. Addy, 20 when contemplating about the activity progress mentioned: *"I feel I am a strong person that can do it and I can do more"*. Also, some felt AGON app gave them the courage to do more physical activity, Dean,19 exclaimed: *"It's not about keeping me in the comfort zone, it's attaining the goal and being able to say – "I'm going for more""*.

5.2.3 Hedonic Aspects. On a few occasions, participants expressed some feelings of sadness when looking at the history of steps. Al, 20 clarified: *"I felt bad when I saw I had less than 3000 steps, I felt powerless knowing that I could not increase my step counts."* Similarly, Gigi, 26 explained: *"When I saw my history [feature], I got disappointed because there were so many days with 400 steps, so little! I said to myself: "How is it possible that I walked so little?" So it was sad, like depressing."* Some of our participants experienced joyful feelings while using the history feature, Kary explained: *"In the history tab, I started with 2000 steps, next week I reached 4000 and that motivated me, it is like I can do more each day. When I moved forward [in step counts] I felt joy!"*. These statements illustrate the potential of the step tracking apps or services alike to incorporate hedonic aspects of both positive and negative experiences after physical activity beyond simply visualizing dry statistical summaries.

Collectively, these reflections and reactions helped illustrate how being aware of the physical activity level pushes individuals to be more rigorous in evaluating their performance and therefore experimenting with various emotions related to their activity.

5.3 Relatedness Support Feature

Our data corpus yielded insights into our participants' perception of the *relatedness* support feature of the app. It revealed subtle connections that relate to their overall motivation to exercise and provoked the comparison of their own results against those of other participants. We distilled three empirical categories from our data corpus: (1) companionship; (2) comparison with others doing physical activity; as well as (3) the feelings of curiosity concerning others' activity.

5.3.1 Companionship. Participants felt they were not the only ones performing the walking activity because they could see the step count increments from others. For example, Kary, 22, when reflecting on the feeling generated by the peers comparison feature mentioned: *"I am not alone, when I see the list I think: "these other people are doing physical activity somewhere else [around the city]."*. Consequently, the ability to see the step counts from other participants provoked personal motivations to walk more. This was described by Anny, 22: *"It is super interesting to see the steps counts from other participants, in addition to mine. I think it is a good motivation."*

5.3.2 Comparison and Competition. Even though AGON app did not explicitly offer a competition functionality, participants perceived a feeling of competing against each other to score a higher number of step counts. For example, Nicky, 19 mentioned: *"I should go out and walk more, because others are walking more."* Similarly, Kary, 22 echoed this through indicating the peer pressure the app triggered: *"I found myself thinking, this person has more steps than I do, I will go to the park so that I will have more steps than he does."*. These quotes might also be indicative that the participants were acting out of guilt. However, we could not find support for this in the remainder of the data we collected.

5.3.3 Curiosity. Some participants revealed the urge to be constantly aware of the level of physical activity from other participants and why they have walked that particular number of steps. For example, Teb, 28 reported: *"I noticed that I walk more than other people using the app."* In turn, AGON app provoked speculations about possible activities and routines of other people: Kate, 22 explained: *"I found myself thinking, she has walked so little, what might she be doing?"*.

In sum, these insights demonstrate the importance of the social features of the app. Even incidental or unintended interactions with other people through sharing of peer statistics (e.g., in the form of leader boards) allowed our participants to interact with others by comparing, competing, and keeping their physical activity status present.

6 DISCUSSION

The key to any behavior change is the development of intrinsic–or self-determined–motivation towards the target activity. Self-Determination Theory [52] is a well-established and empirically validated approach to evaluate behavior-change interventions. More than four decades of empirical research has demonstrated that the basic psychological needs posited by the SDT are predictive and reliable mediators to motivation [6, 29, 43, 52, 65]. SDT has already been studied and applied in the field of HCI to enable behavior change. However, the road to translate this theory into concrete design guidelines is still long, and scholars are asked to "make decisions about *which* functionalities to support and *how* to implement such functionalities." [34] Building on recent work [66], which mapped specific app functionalities to the SDT, we contribute a concrete design of a pedometer app, whose design originates from the theory. It provides three features specifically tailored to support the basic psychological needs of its users. As we will detail in the following subsections, our findings also contribute empirical evidence that Agon users experienced feelings of self-control, empowerment, and comparison with other participants. These findings are encouraging and will have to be further validated with quantitative research, as discussed in Sec. 6.4. Of course, the implementation we tested in the current study is not the only possible way to provide support for autonomy, competence, and relatedness. The discussion with our participants revealed additional avenues of design and research that we will discuss in the subsections below. Finally, we contribute recommendations for other researchers who might want to study behavior-change technology in the wild (see Sec. 6.5).

6.1 Informed and Personalized Choices Supports Autonomy

While reviewing the perceptions derived from using the goal-setting feature of our app, we noticed that participants elicited feelings of *owning* the decision about setting their weekly step-goal. Even though the step-goal increase suggestion came from Agon, participants noticed they decide to pursue the goal or not depending on how much effort they foresee it implies. These feelings are aligned to the SDT *autonomy* definition, which states the need of an individual to experience ownership of their actions [52, p. 86].

Other perceptions captured from using the Agon's goal-setting feature show that when participants had information about their level of physical activity (e.g., average daily step-counts) to make a decision, they displayed effort and determination to achieve the objective. According to what the SDT postulates, feelings of effort and determination are expected to arise when individuals make good choices after thoughtfully considering the relevant options and information [52, p. 462]. Further, this observation resonates with previous studies on physical activity in sport psychology, where researchers established that when goals are set autonomously, they positively predict effort, and consequently, goal attainment [57, 58]. Our study extends this research by incorporating tailored and specific goals (i.e., "walk 7550 steps this week") and not generic open goals (i.e., "improve your upper body strength") like Smith et al. [57, 58] do; differentiating in the ability to set goal metrics.

Another exciting aspect that stood from our findings is the positive reception of a *personalized* weekly step goal. Participants felt more inclined to accept a weekly step goal increase since this increment was tailored to their previous week's performance. The suggested increase of 5% was perceived as achievable –optimal– by our participants. The concept of optimal challenge was already discussed within the SDT [13], and it has been empirically tested in immersive games [48, 49]. Similarly, we see the value of applying this concept to behavioral change scenarios, such as those featured in modern fitness apps. This approach explains why participants reported they accepted the weekly goal increases.

In sum, these observations extend prior research in the following ways: (1) we provide an initial attempt towards translating the SDT *autonomy* construct to Agon's goal-setting feature; (2) previous research allowed individuals to self-set their goals without activity-related information to make a knowledgeable decision (e.g., [10, 28, 42]), or through a self-reported baseline (e.g, [33]), we extend this design space by improving the individual's ability to set goals by making autonomous and informed decisions; (3) the positive response of our participants to the suggested weekly step goal increase is significant because it outlines the potential of personalized goal increments and how this can engage participants to achieve the step goals they have committed to.

Therefore, these findings suggest that app designers might want to provide users with information (e.g., how much effort is needed to achieve a goal, personal activity performance) to contribute to more autonomous decisions and foster goal attainment. Furthermore, designers should suggest adaptable goals to each individual's ability level [3].

6.2 Performance Monitoring Supports Competence

While reviewing the perceptions derived from using our app's history feature, we noticed that participants elicited feelings of progress and empowerment concerning the walking activity. We also noticed that in some occasions these feelings were positive (e.g., feeling joy due to making progress toward the goal), while in other cases expressing negative feelings (e.g., the disappointment caused by not progressing towards the goal). The former feelings are aligned to the SDT *competence* definition, which states the need of feeling effective in one's interactions [52, p. 86]. However, concerning the latter feelings, we believe *Agon*'s design could be improved. In moments where despite not making progress towards the exercise goal, the app could provide information that may encourage alternative ways to fulfill the objectives (e.g., display a message with the text: "Keep trying. There are 3 more days to go!").

Another highlight in our findings is the eudaimonic effect [39] of striving towards one's personal best evoked by the app's use. By observing their daily-step records and history, participants aimed for a constant need for fulfillment and self-improvement.

Other perceptions captured from using the Agon's history feature show an increase of participants' reflection on their physical activity and, in turn, this reflection contributed to motivating them to reach their step-goal. This self-reflection produced by the history feature relates to previous research, demonstrating that having a display that supports activity-awareness may lead to positive outcomes such as keeping the participants' physical activity levels and engagement throughout research interventions [9]. Agon app extends this display approach by using a two-column list with past weeks and steps, allowing time-progress comparison; this is limited in the garden metaphor of Consolvo et al. [10]. Participant's reflections on their own –effective– performance and the consequent positive effect on their sense of competence were expected as the SDT postulates [52, p. 154]. This finding is relevant because it supports the importance of providing personal activity-related information to individuals to increase their sense of competence.

In sum, these observations extend prior research in the following ways: (1) we provide an initial attempt towards translating the SDT *competence* construct to Agon's history feature; (2) previous research provides users with progress bars (e.g., [54]) showing a single progress indicator without the option to compare to previous scores, some others use line or bar graphs (e.g., [31, 42, 44]) allowing comparison between days of the same week, some others allow score comparison with just the competition leader (e.g., [28]). We contribute to this design space by allowing users of Agon to visualize and reflect on a broad time frame (one year). In our design, we enabled this exploration by providing a scrollable two-column text, displaying the list with past days and their related steps. (3) our participant's positive response to the history feature is significant because it outlines the power and intention that rises from participants when feeling capable of achieving the step goals they have committed to.

Therefore, these findings suggest that fitness app designers, who are interested in supporting users' attainment to their fitness goals, should: i. provide elements that increase the awareness of the activity (e.g., steps-history), and ii. cater to positive feelings (e.g., encouraging messages when bad performance happen).

6.3 Comparison with Peers Partially Supports Relatedness

While reviewing the users' perceptions derived from using the peers comparison feature of our app, we observed two types of competition behavior among our participants. Some participants compare their step count with that of other participants through the peers comparison feature (see Figure 2d). The SDT scholars define this behavior as a direct competition, which occurs when players struggle against each other to maximize their success. In contrast, other participants perceived the daily step goal as a competition with themselves. The SDT considers this behavior an indirect competition [52, p.488], which occurs when people compete against themselves when performing better than what they have done previously [52]. Developing mechanisms that foster indirect competition can be significant to fitness app designers interested in skill-building and performance, both reflected in the individual's adoption of mastery goals ([52], op. cit.).

Our relatedness insights showed a partial support of the peers comparison feature on the corresponding BPNs. More specifically, participants felt companionship, meaning they were not the only ones in the study doing physical activity, which in turn increased their motivation to be more physically active. Because of this perception of having a companion, they compared and competed with others (as previously mentioned). However, participants did not perceive themselves *connected* to other participants. This insight leads us to reflect on why the peers comparison was not effective in developing a feeling of connectedness with others. We believe that the relatedness-support feature did not produce an anticipated effect due to two factors. First, participants did not know whom the other people on the list were, producing a lack of empathy and connection with others. Second, we did not place participants in groups comprising people with same physical activity levels. An alternative group assignment –which grouped participants who had similar performance– might have increased the participants' self-efficacy evaluation. This insight opens up an opportunity to explore other designs for relatedness-support features. For example, placing individuals in groups or circles (which might develop a sense of team) and developing a sense of competition against other groups, instead of competing at the individual level. Therefore, these findings suggest that fitness app designers who are interested in supporting meaningful connections between users should: i. provide elements that increase the perception that more people are doing the same activity (e.g., a list of users pseudonyms with the option to display user information like name, age, hobbies.), and ii. foster the feeling of between-user connection (e.g., create competitions between familiar with each other and with similar physical activity levels).

6.4 Future Research and Design Directions

The subjective accounts collected in this research demonstrate that Agon provided support to the autonomy, competence, and relatedness of our study participants. *Would this support be sufficient to motivate the participants to increase the physical activity in their routine?* Unfortunately, the current research is unable to answer this question comprehensively. In this study, we learned that physical activity levels might drastically change from one week to the next due to seasonal effects (e.g., holidays), weather conditions, or other schedule constraints. We also discovered a large variability of behaviors associated with physical activity levels in the sample population: some people might regularly train, while others might walk or run only sporadically. It is necessary to conduct longitudinal studies spanning multiple months and involving hundreds of participants to demonstrate the effects of behavior-change technology. This experimental design might allow researchers to average out participants and seasonal effects and demonstrate the long-term impact of behavior-change technology.

Furthermore, in this study, we tested the three features supporting the BPNs concurrently. However, it would be valuable to understand whether these features need to be available simultaneously to yield benefits to the app users. *Would offering only one (or two) features provide incremental support to users?* A full factorial design, assigning different combinations of features to other user groups, would need testing to answer this question. Such a study can produce quantified observations to relate each feature –or combination of features– to physical activity levels.

From a design perspective, the interviews we conducted suggested exciting avenues to explore further. Several study participants mentioned having a hard time agreeing to the increases in physical activity recommended by Agon on specific days because of personal or work commitments. In the future, designers might develop *autonomy* features that could allow users to adhere to personalized goal increments and customize the day of the week these goals are feasible. Also, our study participants mentioned that the *competence* feature supported their self-reflection. However, none of the participants said they had used this information to follow week-by-week progress, perhaps, because of an additional cognitive load required to infer this information. Furthermore, designers might highlight non-obvious trends in the data series to aid data exploration for end-users. Finally, as discussed in Sec. 6.3 designers might want to develop *relatedness* features that support optimal [13] and coopetitive [67] challenges. We believe these design ideas could also inspire the designers of supporting technologies in other behavior-change domains (e.g., acquiring new skills, subscribing to a conscientious consumption lifestyle, lowering one's ecological footprint).

6.5 Barriers and Recommendations when Running Research on Behavior-Change Apps

The current study made us reflect on two critical aspects of researching technology that aims at supporting behavior change: (a) providing enough time to study participants to *adjust to the intervention*; and (b) *considering the ecosystem* upon which the deployment of interventions occur. Concerning the first aspect, our participants installed the app on different days of the first week of the study, interacting with the app at varying frequencies, and all had periods of unavailability throughout the month-long study. The analysis of the diaries revealed that in most cases participants developed: a concrete understanding of Agon only towards the end of the study. In hindsight, we might have designed a more prolonged deployment to allow participants to experience more opportunities of support provided by the app. The support provided by behavior change apps becomes meaningful only when this is provided close to the target activity the intervention is aiming to change (e.g., walking or running). Given that the target activities often occur sporadically (e.g., once or twice a week), the observation window of user studies must necessarily exceed several expected occurrences of the target activity. Therefore, we recommend researchers define the length of the user study on based on the typical frequency of the target activity in the study population. For instance, with the daily performance of target activities, a study spanning three to five weeks could be sufficient to provide exposure to the intervention. A lower frequency of occurrence of the target activity must reflect in a longer observation window.

Concerning the second aspect, we noticed that our study participants sometimes had difficulty accepting suggested increases in physical activity. Not because they did not want to, but because of schedule constraints or improper conditions (e.g., no lovely places for a walk during the lunch break). As discussed in the previous subsection, this made us consider that an improved version of the Goal Setting feature could have provided more flexibility to allow our participants to choose *when* was best to perform the extra activity. Most behavior change interventions are oblivious to the constraints existing in the users' lives and cannot personalize the recommendations to different life circumstances, unavailability, and logistic constraints. This lack of consideration for the ecosystem in intervention deployment reduces its impact. From now on, we recommend designers explore strategies to capture and model this ecosystem and allow users of behavior change apps to schedule activities around constraints.

6.6 Limitations

We want to acknowledge a few limitations of our study. Since, we deliberately opt-in for a qualitative research approach our findings may not and are not intended to be generalized to other domains. Our approach allowed us to develop a rich and descriptive account of participant perceptions of the Agon app. A future longitudinal study could capture objective and more detailed accounts of an intervention's effectiveness based on the proposed design of Agon.

Furthermore, our study was limited to one particular embodiment of the BPN supportive features. Studying (and comparing) alternative designs might reveal specificities of the features that we could not capture in this study.

Finally, given that we deployed our recruitment fliers on a university campus, we recruited participants in their 20s and 30s. We purposefully aimed for young adults since they are often more active and more involved in sharing personal experiences online [1], and generally have emerged as rapid adopters of digital technology [18]. However, this strategy undoubtedly limits the generalizability of our findings to older users. Future research should recruit a more heterogeneous sample from various cultural, geographic (e.g., suburban, rural), and demographic contexts.

7 CONCLUSION

We explored the perceptions and reflections of 49 individuals from the 4-week field deployment of a Self-Determination Theory-based mobile app. In this paper, we made two primary contributions. First, we present a novel design of a fitness app distilled from the taxonomy of app features based on the SDT. Second, we presented insights on how the perceptions of the app features supported *autonomy*, *competence*, and *relatedness* needs. We hope that our study will inform and inspire future research in personal and persuasive computing that looks at behavior change practices and interventions within the context of physical activities and beyond.

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A SUPPLEMENTARY MATERIAL

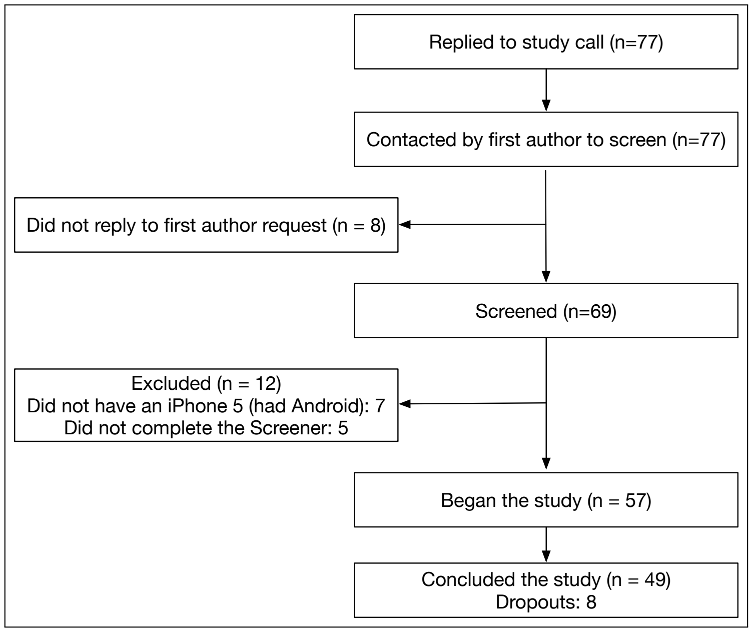

Figure 3: Flowchart showing the recruitment process for Agon study.