

Understanding People's Experience for Physical Activity Planning and Exploring the Impact of Historical Records on Plan Creation and Execution

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ABSTRACT

Making and executing physical activity plans can help people improve their physical activity levels. However, little is known about how people make physical activity plans in everyday settings and how people can be assisted in creating more successful plans. In this paper, we developed and deployed a mobile app as a probe to investigate the in-the-wild physical activity planning experience for 28 days with 17 participants. Additionally, we explored the impact of presenting successful and unsuccessful planning records on participants' planning behaviors. Based on interviews before, during, and after the deployment, we offer a description of what factors participants considered to fit their exercise plans into their existing routines, as well as factors leading to plan failures and dissatisfaction with planned physical activity. With access to historical records, participants derived insights to improve their plans, including trends in successes and failures. Based on those findings, we discuss the implications for better supporting people to make and execute physical activity plans, including suggestions for incorporating historical records into planning tools.

CCS CONCEPTS

- Human-centered computing → Empirical studies in ubiquitous and mobile computing.

KEYWORDS

Physical Activity, Planning, Self-reflection, Mobile Health, Personal Informatics, Qualitative Research

ACM Reference Format:

Kefan Xu, Xinghui Yan, and Mark W. Newman. 2022. Understanding People's Experience for Physical Activity Planning and Exploring the Impact of Historical Records on Plan Creation and Execution. In *CHI Conference on Human Factors in Computing Systems (CHI '22), April 29-May 5, 2022, New Orleans, LA, USA*. ACM, New York, NY, USA, 15 pages. <https://doi.org/10.1145/3491102.3501997>

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CHI '22, April 29-May 5, 2022, New Orleans, LA, USA
© 2022 Association for Computing Machinery.
ACM ISBN 978-1-4503-9157-3/22/04...\$15.00
<https://doi.org/10.1145/3491102.3501997>

1 INTRODUCTION

Regular physical exercise helps people be more healthy by reducing the risk of chronic diseases, including cardiovascular diseases and Type 2 diabetes [57], while also boosting people's mental wellbeing [45]. To maintain good health, adults are recommended to do at least 150 minutes of moderate-intensity aerobic physical activity (e.g., walking, jogging, and cycling) per week [47]. However, less than 25% of American adults meet this guideline [33], with 25.7% of American adults reporting sitting for more than 8 hours per day, and 44.6% being physically inactive [62]. Several barriers prevent people from being physically active, including a lack of time and motivation [12, 22, 54, 58].

Researchers have sought to leverage mobile health (mHealth) technologies to support people with their physical exercise, as such tools offer capabilities of tracking and helping people reflect on their physical activity [15, 24, 27, 51]. Planning for physical activity has been found to be an effective strategy [42] to transfer a person's intentions into actions, thus helping individuals be more physically active [25]. Prior work has explored how digital technology could support people to form effective action plans by specifying when, where, and how to perform physical activity [23, 48, 66], thus improving their physical activity levels [20].

Though supporting people to specify their plans helps them transfer their intentions of engaging in healthy behavior into action [16], individuals still face several challenges in creating and executing their plans. Individuals' performance of physical exercise can be influenced by contextual factors (e.g., activity types, environment, and social factors) [53]. Their physical exercise plans can be disrupted by personal (e.g., emotion, perceived lack of time) and environmental barriers (e.g., weather, temperature) [22]. Prior literature suggests utilizing contextual factors to support people in identifying the "sweet spots" in their schedule, where individuals are more likely to perform physical activity [46]. Still, it can be difficult for people to foresee unexpected events (e.g., impromptu social events, emergencies, and sudden exhaustion) when making plans, which puts their plans at risk of being disrupted [46].

Sniehotta et al. argue that planning is grounded in personal experience and suggest that planning might be more effective after participants have had experience with the intended activity [56]. Prior work suggests that making associations between collected physical activity information (e.g., step counts and energy expenditure) and contextual information (e.g., activities and location), may potentially help people be aware of opportunities for physical activity [40]. When looking at self-collected personal data, people are interested to see their trends (e.g., whether their activity levels

go up or down) and patterns (e.g., the day of the week that they are more active) [15, 39]. It has been suggested that people can reflect on past experiences and leverage that reflection to plan for future activities by imagining future events [59]. While prior work suggests that historical information about one's physical activity may help people plan, it remains unclear how people would interpret and further leverage their historic planning records to inform future planning, and whether they can utilize historical information to deal with challenges in plan execution.

To better understand people's experience of physical activity planning in the wild and how historical planning records might affect people's planning and execution for subsequent physical activity, we conducted a study that aims to answer the following questions:

- (1) How do individuals plan for regular physical activity and execute their plans on a day-to-day basis?
- (2) How does the presentation of historical planning records impact their identification of future opportunities for physical activity?

To answer these questions, we designed and developed two versions of a physical exercise planning app named Physicify, as probes to understand people's experiences of planning without and with historical records. Physicify 1 provided users with the basic experience of planning and reporting regular physical exercise without historical reference. Physicify 2 allowed users to refer to their historical planning data when planning for physical exercise. We recruited 17 participants to participate in a 28-day user study, during which they used the app to plan first without and then with historical records, each for 14 days. For each participant, we conducted three interviews to understand their experiences of planning and performing regular physical exercises without and with historical records.

The series of interviews started with understanding people's planning experience in the wild, where we identified factors (i.e., routines, anticipated energy level, and past experiences of performing physical activity) that people would use to specify planning conditions (i.e., activity type, start time) in their daily lives. We also found that people faced several barriers in their plan execution, including being disrupted by unexpected events, being affected by temporally adjacent events, and physical or mental exhaustion. With historical records presented, participants could potentially derive insights into how to deal with those challenges. Historical records helped participants: (a) identify the likelihood of being disrupted by unexpected events, (b) rearrange their schedule to reduce the impact from adjacent events, and (c) better understand their capability of performing physical activity and determine preferable planning condition.

Overall, this study makes contributions in the following ways:

- (1) We identify factors that impact people's plan creation and barriers that impede their plan execution.
- (2) We offer a description about how people derive insights from historical planning records in the field, and how those insights help people improve plan quality and deal with barriers in plan execution.

- (3) We discuss how digital tools could better support people's planning by helping them make sense of historical planning records and developing planning strategies accordingly.

2 RELATED WORK

In this section, we review previous studies from three aspects: (1) physical activity planning and its challenges; (2) research and designs that support better and more successful physical activity planning; and (3) the use of historical records to support self-reflection.

2.1 Physical Activity Planning and Challenges

Physical activity plays an important role in people's physical and mental well-being [6]. Performing regular physical activity has been shown to reduce the risk of chronic conditions [56, 57] and reduce stress and depression [45]. Even performing moderate physical activity, such as walking, jogging, and bicycling, helps reduce the probability of negative health outcomes [29, 49]. Sherwood et al. identified several determinants of physical activity, including motivation, time, self-efficacy, and exercise type [54].

Planning has been found to be an effective strategy to help people maintain regular moderate physical activity [7, 41]. When making plans, forming implementation intentions by specifying if-then conditions helps people transfer their intentions into actions [63]. The if-then planning connects an anticipated situation (i.e., when, where) with the action (i.e., how) [25]. Action planning and coping planning are two strategies for forming implementation intention [11]. Action planning refers to the planning method of specifying when, where, and how to perform a behavior, while coping planning refers to identifying potential barriers that might impede plan execution. An effective if-then plan needs to be as precise and viable as possible [19, 20]. Several planning components contribute to the specificity of plans, including activity type, the day of the week, the time of day, the place, and the activity's duration [19]. However, Vet et al. found that it's difficult for participants to specify on what days or at what time of the day they would act, making their if-then plans less effective [19].

Individuals face several challenges when executing their plans. People's plans compete with other events and will only be enacted when appropriate conditions are met [67]. Contextual factors, such as weather, social factors, time, and other activities, impact how people create and execute their plans [46]. Also, self-efficacy has been shown to be a moderating factor in plan enactment: people who are optimistic about their capabilities to control their behaviors are more likely to translate their plans into actual behavior [42]. Thus, a successful plan execution requires individuals to anticipate contextual conditions that support the intended physical activity [46] and have a clear understanding of their capabilities. Though people can identify such "sweet spots" in their planning process, their plans are still vulnerable when facing unexpected or unplanned events, including impromptu social events and emergency situations [46]. Therefore, in this study, we endeavor to better understand challenges in individuals' plan execution and how they deal with those challenges.

2.2 Research and Designs that Support Physical Activity Planning

Prior research suggests several ways to support people's physical activity planning. Text2Plan explored if text messages could affect individuals' action planning [43]. Lee et al. demonstrated that self-experimentation can be used as a way to help users create their own personalized behavior-change plans [36]. Wang et al. presented a mobile-based personal mobility pattern visualization app to assist people in making better walking plans for reducing sedentary behavior [64]. DayActivizer collects activity data from the user and automatically recommends activities in the if-then format, and has demonstrated that a lack of contextual information causes the recommendation to be less effective [20]. HeartStep leverages users' contextual information (e.g., time of day, day of the week, weather, etc.) to send them contextual-tailored information, and has shown that actionable and specific suggestions can help individuals engage in the suggested activity [34]. PlanSourcing explores creating behavior-change plans for individuals by strangers and friends, and has suggested that personalized plans that reflect on goals, routines, and preferences are positively received by individuals [3]. CrowdFit evaluates the idea of using crowdsourcing to create exercise plans for individuals. Participants' capability, access to resources, and schedules are found to be useful information that planners will consider when making plans for their clients [2].

In short, prior studies have examined ways (e.g., sending text messages, self-experimentation, and visualizing mobility patterns) to assist people's planning. Prior studies have also identified factors (e.g., time of day, day of the week, weather, routines, and schedules) that are important for creating plans that are personalized and actionable. Still, there is a lack of an understanding of how people interpret those factors in their historical records to derive insights to improve their planning. We argue for the need to examine the process of how people interact with the factors presented with their historical planning records as a way to inspire future designs to support people's plan creation.

2.3 Reflection on Historical Records

Self-reflection, defined as a process of recalling past experience and using reflection to inform future practice [68], connects people's experience with their intended actions. Prior study shows that user-generated data can be used as a source of self-reflection on behavior [1] and help with decision-making. Li et al. defined the reflection process as people reflecting on their personal information by looking at collected personal data or interacting with information visualizations [38], which helps people decide what action to take [38]. Thudt et al. has shown that digital devices, such as mobile phones and fitness trackers, can help people collect data and facilitate self-reflection. Visualization has been shown as a way to facilitate self-reflection and can provide users with insights into past behavior [60]. LifelogExplorer aims to present users with their past experiences to discover patterns in their reactions to different life events and address stress at work. Results from this study showed that people were able to develop strategies to deal with their stress [35]. Lee et al. found that reflecting on their past experience helped people set up personalized walking plans [37].

When people look at their personal data, they will try to find patterns and trends in their historical data [39]. The history of people's past behavior, which helps them find patterns of failure and success, further contributes to their awareness of physical activity level [15]. It has been shown that reflecting on past experiences improves individuals' well-being in general [10, 30]. Previous studies suggest that evaluating the outcome of past behavior supports formations of if-then plans [26], and reflecting on past experiences facilitates how people imagine and plan for future activity [59]. The Theory of Planned Behavior suggests that people's past behavior can be treated as a source to reflect on the factors that determine the intended behavior [4]. However, few studies have addressed how people could utilize the reflection on previous experiences to inform future planning. In this study, we want to explore how technology could be better designed to support people's reflection on their past experiences and how people could leverage their historical planning records to derive insights and further improve their plans.

3 METHOD

The aim of this study was to investigate people's experiences of physical activity planning on a day-to-day basis and to explore the impact of historical planning records (e.g., planned exercise type, completion status) on people's plan creation and execution. Though planning has been shown to help people maintain physical activity level [42], individuals face several challenges in successfully creating (e.g., failing to specify the time condition in planning [19]) and executing their plans (e.g., being disrupted by unexpected events [46]). Hence, literature has shown a need to assist people in making better and more successful plans. The second aim of the study was to explore the impact of presenting people with historical records (e.g., planned exercise type, completion status) on their subsequent physical activity planning behavior. Historical records are considered potentially helpful because prior literature has suggested that people may be able to reflect on their past experiences and therefore identify future opportunities for physical activity [18]. However, there is a lack of understanding of how participants utilize different contextual information (e.g., day of the week, time of day, and activity type) and previous planning records to improve their physical activity plans. All of these drove us to investigate people's in-the-wild experience of physical activity planning and how they may make use of historical records to create better plans. To achieve these goals, we designed and developed a mobile app, Physicify, as a probe and conducted a two-phase study where we first probed the participants' planning experiences in their daily lives (planning without historical records), and then provided them with their historical planning records.

We divided this 28-day study into two phases to compare the participants' planning experiences first without and then with historical records (Fig 1). In the first phase, which lasted for 14 days, participants planned regular physical exercise without any historical data using Physicify 1. This study phase aimed to better understand the participants' experiences in planning physical exercises and the challenges in their plan creation and execution. The first phase also allowed participants to collect planning data points that they could refer to in the second phase. In the second phase,

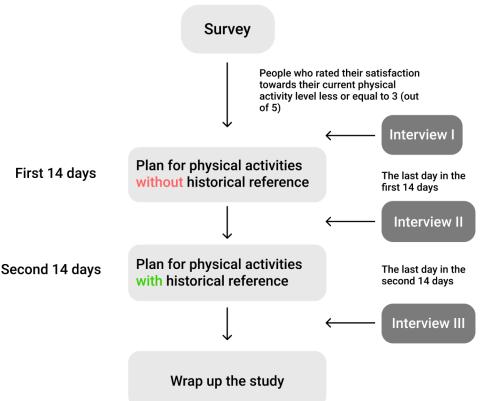


Figure 1: The study was divided into two phases. Each participant participated in three interviews and shared their experience of planning and performing physical exercises on a day-to-day basis

we incorporated historical references into their planning process. Participants were provided with their historical planning data when using Physicify 2 to plan physical exercise. In doing so, we wanted to see if the historical reference helped solve the challenges participants encountered in the previous stage. We required participants to plan and report physical exercises at least 4 times a week to get a full compensation of \$77, in order to have them generate sufficient, usable historical data. As encouragement, the participants could choose to do one extra plan per week and earn \$2 for each extra plan: in total, they were able to earn \$8 for making extra plans.

To understand participants' plan creation and execution experiences in those two phases, we conducted three interviews remotely with each participant at the start of the study, the end of the first phase, and the end of the second phase.

3.1 System Design

To probe the participants' experiences of planning for regular physical exercise and the impact of historical records, we designed and developed two versions of a physical activity planning tool, Physicify. Both Physicify 1 and Physicify 2 are iOS applications developed by the team that were distributed to the participants using Apple's TestFlight service. Both app versions allowed participants to plan and report their physical exercise with participants' plans and reports uploaded to Google Firebase. The major difference between Physicify 1 and Physicify 2 is that Physicify 2 provided the participants with their planning records (e.g., completion status, planned time, and exercise type) and contextual data (e.g., weather, temperature, schedule), while Physicify 1 only allowed the participants to plan and report their physical exercises (Table 1).

We asked the participants to complete a daily report at the end of each day (Fig 2). The daily reports had two forms: If the participants had physical exercise planned on that day they needed to report if they had completed their plans (Fig 2 (1)). If the participants did not have any physical exercise planned, participants needed to report whether they did any physical exercises (Fig 2 (2)). If the

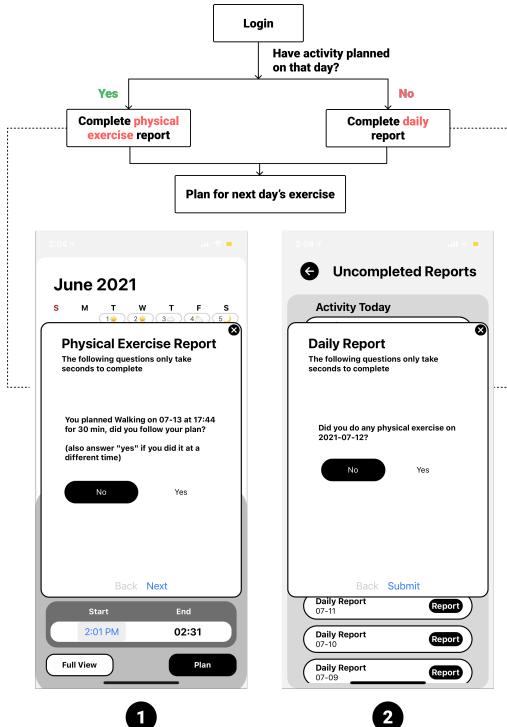


Figure 2: At the end of each day, participants were required to report their plans and plan for a new exercise on a future date. Inside the app, participants could either: (1) report their plan completion if an exercise was planned on that day, (2) report if they did any physical exercises if no exercise planned on that day

participants did exercise in either situation, they were asked to report their satisfaction toward that exercise experience (participants chose from "Unsatisfied", "Neutral" and "Satisfied" [5, 8]). If they did not complete their plan (including being interrupted), they were required to report the reason (e.g., feeling tired, being disrupted by other events) and if they engaged in any other physical exercise. In the interviews, we used the reported satisfaction of each experience to understand if the participants performed the planned exercises in the way they preferred. The participants' reported plans were then categorized into three conditions: (a) completed: the participants carried out the planned physical activity; (b) partially completed: participants carried out a different type of physical activity on the planned date; (c) failure: participants didn't carry out the plan and didn't engage in any physical exercise. This self-report interaction is the same on Physicify 1 and Physicify 2.

To plan physical exercise for the next day, the participants were required to specify the date they wanted to conduct the exercise, the type of exercise, and the start time of the exercise (Fig 3 (2)) [19]. They could add self-defined exercises if they did not find the intended exercise type in the predefined list. The participants were only allowed to plan for one physical exercise on one future date each time in order to better understand how they anticipated future opportunities for performing physical exercise. The participants

Table 1: App Functions: Physicify 1 vs. Physicify 2

Physicify 1	Physicify 2
Plan physical exercise	Plan physical exercise
Report planned physical exercise	Report planned physical exercise
Report days without planned exercise	Report days without planned exercise
Notification on upcoming plans	Notification on upcoming plans
Notification on daily reports	Notification on daily reports
	Historical summary view
	Completed plans vs. total plans
	Number of records under different situations (in color-coded bar charts)
	Calendar view
	Color-coded records
	Weather information
	Temperature information
	Days of the week information
	Google calendar events
	Detail information view
	Weather information
	Temperature information
	Days of the week information
	Plan completion information (completion status, planned time, and reason of failure)
	Daily schedule information

could modify the planned activity by deleting the existing plan and specifying a new plan before the planned date. In this case, the deleted plans would disappear from the participants' screens (both Physicify 1 and Physicify 2) and be marked as deleted in the database. Both Physicify 1 and Physicify 2 sent notifications to the participants to remind them of their plans one hour ahead (Table 1).

At the beginning of the study, we recommended that the participants always open the Physicify 1/Physicify 2 app at the end of each day, complete the report for that day, and then plan for an exercise the following day. Still, the participants had the option to plan for any future date. Both Physicify 1 and Physicify 2 sent notifications to participants to remind them of reporting and planning for a future exercise at 8 pm each day (Table 1).

3.1.1 Physicify 1. Physicify 1's goal was to provide the participants with a basic experience of planning for regular physical exercises (Fig 3 (1)). It would list participants' previous unreported plans in case they did not report their exercise in time. It would also show the participants the exercise they planned for the future. Once the participants completed the report regarding specific exercise plans, the record of that exercise plan would be cleared from the screen.

3.1.2 Physicify 2. Physicify 2 was developed on top of Physicify 1, and it focused on providing participants with the experience of planning with historical planning records (e.g., completion status, planned time, exercise type) and contextual information (e.g., weather, temperature, schedule). Physicify 2 aimed to help participants explore their historical planning records from multiple perspectives (e.g., records on the same day of the week, records under the same weather condition) and reduce the burden of interpreting their records.

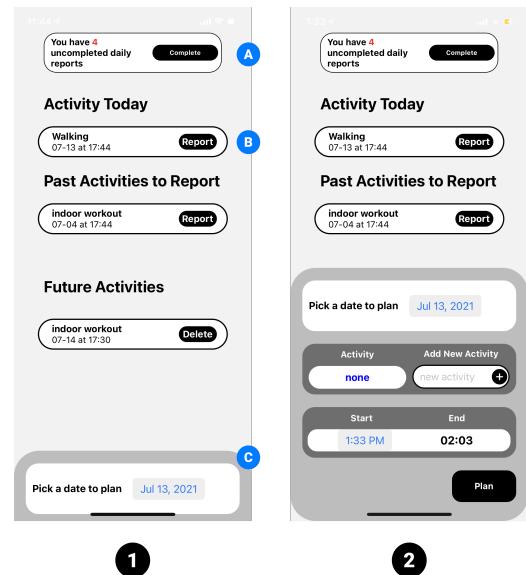


Figure 3: (1) Both Physicify 1 and Physicify 2 shared the same planning panel which asks users to specify the exercise type and the start time (the duration of the physical exercise is 30 minutes by default). (2) Physicify 1 provided participants with a basic planning experience without historical reference on their previous plan completion. On Physicify 1, users could: (A) complete reports regarding days without a physical exercise plan, (B) complete reports regarding the planned physical exercise, and (C) specify planning conditions by dragging up the planning panel

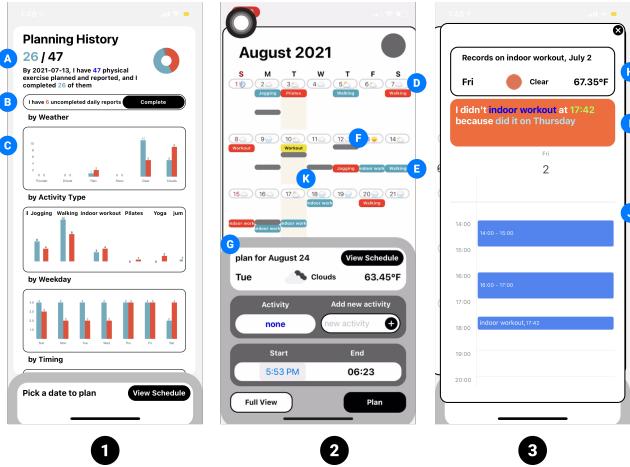


Figure 4: Physicify 2 allowed participants to explore their historical planning data from multiple perspectives and plan physical activity accordingly. (1) On the historical summary view, participants could: (A) view completed plans vs. total plans, (B) complete previously unreported plans, and (C) view their planning records grouped by different conditions in bar charts. (2) On the calendar view, participants were presented with detailed information regarding their planning records, including (D) the weather condition, (E) the physical exercise type and completion status (color coded), and (F) Google Calendar events. When planning a physical activity, participants can see (G) the contextual (i.e., day of the week, weather, and temperature) information regarding the date they choose, and (K) highlighted records on the same day of the week. (3) By clicking on the planning records on the calendar, participants could see (H) the contextual information regarding a specific record (i.e., day of the week, weather, and temperature) (I) the details of their previous plans (e.g., whether the plan was completed, the planned exercise, the start time, and the reason for the plan's failure) and (J) how the physical exercise was planned within their schedule.

Based on what they reported (e.g., whether they completed the plan, if they did any other physical exercise instead, the reason for failure) in the first phase, the participants' historical planning records were visualized and presented in two views: a historical summary view and a calendar view. We color-coded the participants' planning records on both views (red represented uncompleted plans and green represented completed plans). The historical summary view and the calendar view were organized as cards on the same screen so participants could easily swipe between them.

To give participants a clear overview of their plan completion under different conditions (e.g., weather, type, days of the week, and time-of-day), we used the historical summary view to group the participants' planning records. We used bar charts to represent the users' planning records since the bar chart had been found to be more readable and comprehensible [61]. On each bar chart (Fig 4 (C)), the height of the bar indicated the number of the records

(e.g., 5 uncompleted planning records on Wednesday, 10 completed planning records before 12 pm). The historical summary view also offered an overview of the participants' overall completion rate (plans that they completed versus the total number of plans they made) at the top (Fig 4 (A)).

To allow the participants to further explore and interact with their planning records, we also designed calendar views that listed the participants' Google calendar events (Fig 4 (2)): the gray boxes) and physical exercise plans (Fig 4 (E)) (both future plans and previous plans) in a calendar format. As suggested by Vet et al., a calendar view could potentially support people in specifying "when" conditions in their planning as it allows people to respond to days of the week and time of day in their planning [19]. The personal information (e.g., event title, description, location, etc.) associated with their Google calendar events had been removed for privacy concerns. The boxes representing their plans had the name of the planned exercise and were color-coded to indicate the completion status (green represented participants successfully executed the plan, red meant they failed to execute the plan and did not do any physical exercise on the planned day, and yellow represented they did not follow the plan but did other exercises instead).

Prior study has shown that contextualized data can facilitate the recall of personal meaningful moments [28] and the sensemaking of personal data [50]. Moreover, people's planning process involves consideration of multiple contextual factors [46]. With contextual information presented, people can make associations between physical activity and contextual factors, thus increasing the awareness of physical activity opportunities [40]. Therefore, contextual factors in people's activity records can potentially support people connecting their previous experiences with future opportunities when planning for physical activity. Prior works identified several contextual information, including temporal factors (e.g., time-of-day,), weather, and activity, that people would reflect and rely on when evaluating previous experience data and identifying future opportunities in planning [34, 40, 46]. By involving contextual factors in users' planning and reflection process, we wanted to further understand how historical records changed the way of reflecting on contextual information and identifying future opportunities. In consideration of user burden and effectiveness of contextual factors on users' planning behavior, we opted to present users with factors that 1) can be automatically collected and 2) repetitively occur in users' planning and reporting process. Thus, on Physicify 2, we chose to present contextual information from three dimensions: weather (Fig 4 (D)(G)(H)), temporal factors (including schedule (Fig 4 (J)), time-of-day (Fig 4 (I)(J)) and days of the week (Fig 4 (E)(G)(H))), and activity data (activity type, completion status (Fig 4 (E)(I))). On the calendar view, the participants' events (i.e., events from their Google calendars, the planned exercises, and the planning records) had been divided into two rows based on whether the events started before 12 pm or after. Events in each row were ordered by their start times. Depending on the date they chose, all the events on the same day of the week would be highlighted (Fig 4 (K)). The weather on each date was indicated by an icon beside the date (Fig 4 (D)). By clicking on a date, the participants could see the details regarding that day (Fig 4 (3)), including the weather and temperature information (Fig 4 (H)), their plan completion information details (Fig 4 (I)), and their schedule on that day (Fig 4 (J)).

To plan a new physical exercise using Physicify 2, participants first selected the intended date on the calendar view (Fig 4 (2)-(E)). The planning panel (Fig 4 (2)(G)) would pop-up and show participants the weather and temperature on that date. Participants could first view their schedule on the intended date (same view as Fig 4 (3) but without completion information). When they were specifying the activity type and the start time, a filter would be applied to the calendar view to show them only similar records (e.g., records with the same activity type, planned before or after 12 pm, or both). The participants could remove the filter at any point without affecting how they specified their plans. The filter provided the participants with a way to look back at similar records when planning for future exercise.

3.2 Participants and Recruitment

Participants were recruited through department mailing lists at the first author's university. Recruiting emails contained a screening in which we asked respondents to indicate their satisfaction with their current physical activity level on a Likert scale from 1 to 5. Similar to the sweet spot study [46], respondents who reported their satisfaction as equal to or lower than 3 were eligible to participate in this study. Eligible participants should be between the ages of 18 and 55, have no disabilities or health issues that would prevent them from engaging in regular moderate aerobic physical activity, and have access to a smartphone with an operating system higher than iOS 10.0.

We recruited 20 participants at the start of this study. All participants were either current students (Undergraduate students, Master's students, and Ph.D. students) or alumni at the first author's school. Three participants quit in the middle of this study due to scheduling conflicts or issues with installing the Physicify app. Their data was excluded from the final data analysis. Out of the 17 participants who completed the study, one was male and 16 were female.

3.3 Interviews

We conducted interviews to understand the participants' experiences of physical activity planning on a day-to-day basis and explore the impact of historical planning records. Interviews were conducted by the first author using a semi-structured interview protocol. All interviews were audio and video recorded, and they were later transcribed and coded.

3.3.1 Interview I. The first interview, which was held at the start of the study, aimed to understand the participants' prior experiences of performing physical exercises and their barriers. We also used the first interview to understand the participants' personal characteristics (e.g., preferences, daily routines) in performing physical exercise. The participants were asked to walk through their recent experiences of conducting physical exercises during this interview. After the first interview, the participants were instructed to install Physicify 1.

3.3.2 Interview II. 14 days after the first interview, we held a second interview to understand the participants' plan creation and execution experiences (without any historical reference) for the prior two weeks. We started by asking them to walk us through

one of their recent experiences of planning physical exercise. We then asked them to plan a physical exercise for the next day in front of the investigator and verbally walk us through their thinking process. The participants were then asked to walk through critical incidents (e.g., completed the plan but unsatisfied, outliers regarding planning style, failed to follow the plan, changed the planning condition, etc.) on their records. To help them recall their experiences, we prompted the participants with information regarding particular records (e.g., exercise type, time of day, completion, and satisfaction). After the second interview, the participants were instructed to install Physicify 2.

3.3.3 Interview III. After using Physicify 2 for 14 days, the participants were invited to the last interview, which was intended to understand the impact of historical records on the participants' planning behavior. From this interview, we wanted to understand the participants' experiences of planning physical exercise with historical reference. To better understand how the participants perceived and interpreted their historical records on the calendar view and historical summary view, we asked them to first go through their planning records on Physicify 2 by sharing their screen and speaking aloud about anything that came into their minds. To see if historical records helped to inform the participants' planning, we asked them to plan a new exercise for the following day in front of the investigator and verbally walk us through their thinking processes. To understand if historical planning records helped the participants deal with barriers in their plan creation and execution, we looked back into the participants' responses regarding challenges in the second interview and asked them if anything changed. With their records shared on the screen, we asked them to walk us through the records we found interesting (e.g., change in planning style, patterns, etc.).

3.4 Data Analysis

We audio-recorded and video recorded all the interviews, which were later transcribed and coded using in vivo coding [52]. Codes were first grouped to address the research questions (e.g., challenges of plan creation, challenges of plan execution, factors affected plan execution, factors affected plan creation), and then re-grouped with the themes that emerged from interviews (e.g., reflecting on historical records). The first author conducted the data analysis by further grouping codes to reveal potential findings regarding the participants' experiences of planning for regular physical exercise. The coded data under each potential finding was then analyzed to evaluate if the finding was valid.

4 FINDINGS

All the 17 participants made and reported a total of 248 (Phase 1: 136, Phase 2: 112) physical exercise plans during the 28-day study. Among the plans they made, participants successfully followed 183 of them (did the exercise as planned). On average, each participant made 15 plans (min=2, max=25). The average completion rate was 70.4% (Phase 1: 75.3%, Phase 2: 65.0%).

Prior to the study, only five participants (P1, P6, P11, P16, P17) had regular physical activity (at least twice a week), while other participants' physical activity levels were low (P5, P10: completely

sedentary) to light (e.g., P4 did some walking infrequently, P8 went to the grocery once a week).

From the three interviews (referred to as I, II, III. e.g., P2_I, -P2_{II}, P2_{III}), we identified factors (i.e., routine, perceived energy, and past experience of performing physical activity) that participants would consider in their plan creation and challenges (i.e., unexpected events, being affected by temporally adjacent events, and physical or mental exhaustion) in their plan executions. We found that participants gained insights from their previous planning and completion records, and could use them to inform their subsequent planning. These insights included: (1) the likelihood of being disrupted by unexpected events; (2) how schedules could be rearranged to reduce the impact of temporally adjacent events; and (3) the understanding of the capability of performing physical activity under different conditions.

4.1 Factors Affect Plan Creation

Prior study identifies several factors that people would consider when planning for physical activities, including time, location, activity, and weather [46]. In addition to those factors, we found that daily routines, anticipated energy levels, and past experiences of performing physical activity also played an important role in affecting how people specified planning components (i.e., start time, activity type).

4.1.1 Routines. Individuals' routines are referred to as typical daily activities that they carry out at different times or days. Over half of our participants (Interview II, n=9/17) indicated that when they tried to find a suitable time for doing physical activity during the second interview, they usually thought of their existing routines that would impact their availability and shape their time preference. For example, P16_{II} preferred to plan physical activity in the morning due to work schedules and plans (e.g., hanging out with friends) at other times of the day: *"It's kind of weird to run in the middle of the day, because you are working [during that period]. And you have to stop, so it's kind of interrupting. And also in the evening, it's quite often to have plans or appointments with your friends. There are more plans already in the evening, but in the morning you don't have any plans normally [...] that's why I prefer morning."* P8_{III} mentioned that it was much easier to plan physical activity on days with routines, such as workdays, compared to days without routines, like weekends: *"[for workdays] my time is more scheduled. At 2 or 3 [pm], I just like, that's my exercise time [since] I don't have other stuff to do, it's kind of helped me to form that routine [of performing regular exercise]. For the weekend, I'm completely free [...] I don't think I can keep my exercise plans on weekends, just impossible."*

4.1.2 Anticipated Energy Level. Anticipated energy level refers to how participants anticipated their future body energy level. From the second interview, we found that some participants (Interview II, n=5/17) would rely on their anticipated energy level to decide when to perform physical exercise. Those participants would also anticipate the impact of physical activities on their energy level to avoid exhaustion or fatigue. P14_{II} sometimes preferred to plan physical exercise in the morning because she anticipated her to be more energetic during that time: *"Normally in the morning, I have more power. I am more active in the morning compared to night."* P6_{II}

would plan physical exercise sometime later after work since she felt tired either immediately after work or late at night: *"I picked time seven [to do exercise] because I don't think it's too late [otherwise] I may actually be really tired. And it's not like right off of work, where I feel like it's a chore to do it. So I think it's a good balance. [Exercising at] seven o'clock, even maybe eight o'clock, is a good balance between just getting off work and giving yourself time to relax and breathe."*

4.1.3 Past Experience of Performing Physical Activity. In the second interview, we found that even without referring to historical records, nearly half of the participants (Interview II, n=8/17) could leverage the information (e.g., time, activity type, mood, satisfaction) in their past experiences of performing physical activity to assist their planning. P5_{II} would rely on her past experience to decide the time of doing future exercise: *"I would think about what I've been doing so far [when specifying the planning conditions], I tend to do exercise around the four o'clock and five o'clock timeframes, so just because of that history, I could just pick those times [when planning]."* P1_{II} would avoid planning dog-walking in the morning because hadn't done that previously: *"Based on my previous experiences, I probably won't walk my dog in the morning and I will say like 4 pm is an educational guess [that I will walk my dog]."* P8_{II} had some less satisfying experiences of doing physical exercise at different times of day (i.e., felt dizzy when doing exercise in the morning, became nauseous when doing exercise right after lunch). When planning for a future exercise, those experiences helped her identify a more suitable time to perform physical activity and avoid a negative impact: *"I tried it once in the morning, it was a disaster. I didn't eat anything, and I feel dizzy immediately after the abs [...] And then another time I ate lunch, and right after lunch I started to do exercise and I started to puke [...] [That's why I] always make my plans after lunch, but some time later after lunch."*

4.2 Barriers in Plan Execution

Our findings from the first phase of the study align with the prior study that unexpected events [46] were one of the barriers in participants' plan execution. Additionally, we found that being disrupted by temporally adjacent events and physical or mental exhaustion also brought challenges to participants' plan execution.

4.2.1 Unexpected Events. Unexpected events were mentioned (Interview II, n=7/17; Interview III, n=3/17) as impromptu events (e.g., unexpected social events, emergencies, and sudden exhaustion) that participants were not aware of when planning and had the potential of disrupting their plans. P12_{II} considered unexpected events as one of the challenges in sticking to her plans since they could happen at any moment: *"I almost always follow the plan, except when I have some sudden unexpected plans. [In that case] I have to cancel the [exercise] plan. [...] I mean, sometimes you just have to go grocery shopping or something like that. [...] I don't know how to take that into consideration because you never know what you may have [other events]."*

4.2.2 Affected by Temporally Adjacent Events. In this context, temporally adjacent events were mentioned (Interview II, n=6/17) as events that happen immediately before or after the planned exercise. When participants planned the exercises within their schedules, the deviation from prior events (e.g., a delay in the prior events) or

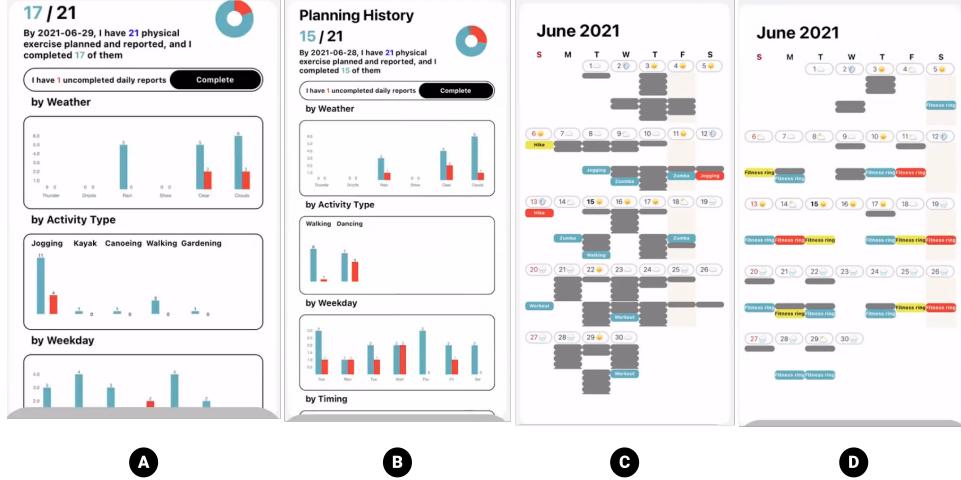


Figure 5: (A) P5's historical summary view: P5 learned from the "by Activity type" bar chart that she did way more jogging than other activities. (B) P2's historical summary view: P2 was surprised that her completion rate of dancing was much lower than walking by looking at the "by Activity type" bar chart. (C) P12's calendar view: P12 grouped her records by days of the week and found that her completion was poor on weekends. (D) P10's calendar view: P10 addressed on her yellow records that sticking the one activity might not be a good idea

the time needed for later events (e.g., leaving enough time to get prepared for later events) could affect their plan execution. P6_{II} planned physical exercise after a school assignment; however, the school assignment took much longer than she expected, which made her fail to do the exercise afterward: *"It was on the 14th, I planned for squats, and I ended up having to do a course waiver for my class. That took a lot longer than expected [...] so I wasn't able to do the exercise."*

4.2.3 Physical or Mental Exhaustion. In this study, participants' physical or mental exhaustion (Interview II, n=11/17) was usually caused by previously performed activities (e.g., working, previously performed exercise). When talking about the difficulties for her to stick to her plans, P16_{II} mentioned that running too intensely caused exhaustion and body pain, which made it hard for her to carry out the next exercise plan: *"When I run too harsh, and the next day, it makes my body really heavy. And my muscles are so tired, and then I can't go out."*

4.3 Participants' Actions in Response to Historical Planning Records

After being presented with historical planning records, we found several changes in participants' planning behavior. In the second phase of the study, participants were able to derive insights to improve their plans by reflecting on their historical planning records. In this section, we describe how participants reflected on their historical records to derive insights to inform their planning. To be noticed, some participants' reactions to historical records happened during the third interview (marked as "(I)", the same in section 4.4) and some are retrospectively mentioned as their practice during the second phase before the third interview (marked as "(P)", the same in section 4.4).

4.3.1 Reflecting on Failure Records. When participants were walking through their historical records, the failure records often (Interview III, n=9/17) drew their attention and evoked further interpretations. When P5_{III} was looking at her events on the calendar view (I), she weighed her failure records as more meaningful records: *"I think the only thing I was really looking at were the two Wednesdays I missed. And then the rest [of my records] was saying that there is a lot of blue, [which indicates that] I was mostly completing exercises I planned for."* When P12_{III} was looking at her events on the calendar view (P), she would first consider the failure records. She would then reason behind her failure records and apply that understanding to her later planning: *"Whenever I am looking at it [the calendar view], I look at it as a whole, so I [usually] looked at the previous two weeks activities [...] but whenever I was planning, it was like okay I wasn't able to do this last Saturday, and it was because of this reason, so I should take it into consideration and then plan."* P6_{III} reported that the color coding made her quickly perceive the portion of the data that indicated the failure (I, P): *"I think the red [records] I [could] quickly perceive that as things I didn't do. The blue [records] would probably take me like two or three seconds [to perceive]."*

4.3.2 Paying Attention to Extreme Values. Participants also paid attention to extreme values in their records. The extreme values in participants' records were values (e.g., completion rate, number of plans) in a group of records (e.g., records of the same activity, records on the same day of the week) that were significantly bigger or smaller compared to other groups of records (e.g., much higher completion rate of a certain activity type compared to other activity types). When P5_{III} was looking at her historical summary view (Fig 5 (A)), she started with the activity that she had the most records with (I): *"And I am happy to know, like how much I was jogging compared to other exercises [15 jogging records over 21 total records],*

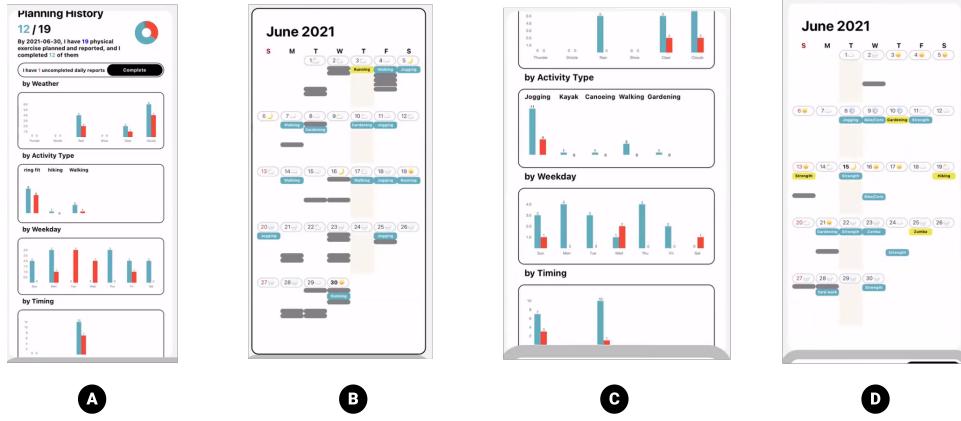


Figure 6: (A) P7's historical summary view: P7 found that she failed to conduct all her plans on Tuesday and Wednesday when looked at the by Weekday bar chart. (B) P3's calendar view: P3 saw that she rarely planned on weekends. (C) P5's historical summary view: P5's completion was better in the afternoon, compared to morning. (D) P13's calendar view: P13 tried different activities at the beginning of the study and referred to those records in her later planning.

regarding the activity type [...] I'm glad I jogged a lot, and I'm happy to see that here." When looking at the historical summary view (Fig 5 (B)), P2_{III} was surprised that her completion on walking was much better than dancing (I): "The bar chart that is showing activities by types is more important and influential on my decisions, because there is a big difference between them [...] [I could see that] I stick with the walking more, I didn't know that the difference is this much, so it's pretty interesting and surprising for me."

4.3.3 Grouping Records Around Common Characteristics. We found that participants could group historical records around common characteristics and make sense of their data. The common characteristics (e.g., same days of the week, same activity type) associated with the records allowed the participants to interpret similar records as a whole. When P12_{III} looked at her records on the calendar view (Fig 5 (C)), she compared her completion status of the records grouped by different days of the week (I): "I could also see that mostly Saturdays [and] Sundays, I was not able to do activities [...] I somehow got an idea that planning on weekends or relying on weekends [may not be reliable], since you have a very ambiguous plan on weekends." By looking at the calendar view (Fig 5 (D)), P10_{III} found that she had 5 yellow records (that she did not follow the plan but substituted with other physical exercises). Since all those yellow records concerned workouts, she reached the assumption that sticking to one type of exercise might not be a good idea (I): "For the activity type, I have quite five yellows here [of doing the same activity] [...] it would tell me that keeping up on one activity is not interesting enough. And I need to make it more diverse."

4.4 Insights Derived from Historical Records that Informed Planning

By evaluating historical planning records, participants obtained insights into the likelihood of being disrupted by unexpected events, the impact of temporally adjacent events, and preferable planning conditions. These insights support the participants in improving plan quality and dealing with barriers in plan execution.

4.4.1 Identifying the Likelihood of Being Disrupted by Unexpected Events. From the historical records, participants acquired insights into dealing with potential unexpected events. We found that over half of the participants (Interview III, n=11/17) were able to identify the likelihood of being disrupted when evaluating their historical planning records around temporal factors (e.g., time of day, day of the week). By applying this understanding to their planning strategy, some participants (Interview III, n=6/17) reported that it helped them avoid unexpected events in plan execution.

We found that certain conditions (e.g., certain time of day, certain day of the week) in participants' schedules involved higher risks of being disrupted by unexpected events. Those conditions could be addressed by reflecting on temporal factors, such as the days of the week and the time of day, that were associated with historical records. In the second interview, P12_{II} mentioned that she was more likely to have unexpected events on Fridays and weekends: "Usually on Fridays or on weekends, sometimes we just have unexpected plans." P16_{III} mentioned that she was less likely to be disrupted in the morning than other times of day: "Actually morning is good because usually compared to other times like in the afternoon [...] Things rarely happen suddenly in the morning." The historical records provided the participants with a way to identify the likelihood of being disrupted. By referring to the by-weekday bar chart on the historical summary view (Fig 6 (A)), P7_{III} found out that she was less likely to do workouts on certain days of the week when she saw that she failed to carry out all her plans on Tuesdays and Wednesdays (I). She would like to avoid those days of the week in her future planning: "I can see for Tuesday and Wednesday, it's easier for me to not complete the plan, and for other days is easier for me to complete the plan [...] so by this view, I will think about like for Tuesday and Wednesday, maybe I should change." By referring to the records on the calendar view (Fig 6 (B)), P3_{III} saw that she usually skipped the weekends when making physical exercise plans (P); she further reasoned that it was because her weekend schedules were loose, which made it hard for her to avoid being disrupted: "For me like my weekends are

kind of all over the place [anything could happen on weekends]. So I don't typically plan for them. [But] like Friday is the most predictable [...] More often than not. I can plan easier on weekdays rather than weekends."

Participants could develop planning strategies to reduce the likelihood of being disrupted. In general, participants tended to plan physical exercise under conditions with either a higher completion rate or a larger number of plans. P5_{III} tended to plan physical exercise in the afternoon (I), during which her completion rate was higher in the historical records (Fig 6 (C)): "*I have a way higher percentage of successfully completed activities in the afternoon. And that's true, [so] I'm gonna keep planning for the afternoon.*" Some participants (Interview III, n=6/17) discovered the reason behind their disruptions and changed their planning strategy accordingly. After looking at the completion status of her plans (I), P10_{III} found that she could follow her plans better on Sunday and Monday, but not for Wednesday (Fig 5 (D)). She attributed this to a busy schedule on Wednesday and tended to plan more on the days that she was more likely to do exercise and avoid planning on Wednesday: "*I [would] definitely schedule with the workout on Sunday because that's pretty promising and Monday could do, too. Maybe [I should] avoid [Wednesday]. [...] If I look at my schedule, on Wednesday, I have more meetings and [might be] tired or something because of that. If I plan, there's a chance that I won't do that.*" P11_{III} still found it difficult to anticipate unexpected events. Instead, she found that planning under conditions that were less likely to be disrupted helped her avoid unexpected events in general (P): "*I feel in terms of unexpected things happening, I still cannot make a good control for it. But one thing changed, I started to do exercise during the time that I'm more likely to be free [...] I did have some of the physical activities at 3 pm to 4 pm, [because] I usually have nothing to do at that time, and nobody will chat with me during that time.*" P12_{III} identified weekends as a potential time to be disrupted and would consciously avoid planning on weekends (P). P12_{III} reported that this strategy helped her avoid facing unexpected events in plan execution: "*I did not face that [unexpected events] this weekend, because when I planned, I kept in mind that I could not do a few things last weekend. And I could see that I could not do activities on Saturday and Sunday. [...] So I would just leave it on.*"

4.4.2 Rearranging Schedule to Reduce the Impact from Temporally Adjacent Events. Historical records provided participants with insights into how other events impacted their plans, so participants could make changes accordingly. By rearranging the exercise to the place that was less likely to be disrupted by temporally adjacent events, participants were able to better follow their plans.

After looking at the historical records, P5_{III} found that she often failed to execute her plans at 9 am due to getting up late (P). She then figured out another time for physical activity, so her plans would not be affected by the wake-up time: "*[In the first two weeks] I kept planning exercise at 9 am because I thought I'm gonna get up and start my day early. But that never happened, I would sleep past and then be like, Oh well, now I miss my time, so I'm not going to exercise. [In] these last few weeks I realized that I'm not going to actually get up at 9 am so I'm just going to plan to exercise at 1 pm, and then I would actually go out at 1 pm. So that worked a lot better [...] it would just fit in my schedule really well and stuff, so that was nice.*" After

referring to her failure records on the calendar view (P), P10_{III} realized that planning physical exercise as the last activity to do in a day involved too many distractions: "*After everything [happened in a day], I guess, I was like a little tired [...] I really want to go to sleep as early as possible. In that situation, I won't do the exercise [...] I realized that if I keep doing it [the workout] at nine, there will be a lot of distractions, so I decided to reconstruct my whole schedule.*" To avoid being disrupted, P10_{III} started to reschedule her workout before dinner (P), which was identified as an event that involved fewer distractions: "*I decided to move the time [of doing workout] from 9 [pm] to 5 [pm], which is before the dinner, and at that time, I have fewer distractions [...] It gives me a mind that I need to work out at five, like before I eat, or before I go out or something. So it gives me a message that I should work hard before this stuff. [...] It just gives me a better idea that what activities should be before workouts and what activities should be after the workout.*"

4.4.3 Using Historical Records to Determine Preferable Planning Conditions. Through historical records, participants could identify preferable planning conditions that they could perform physical exercises with ease. Participants with little prior experience of performing regular physical exercise found it hard to specify conditions in their plans due to the unsureness of their capability. In those cases, some participants (Interview III, n=6/17) would first try planning physical exercises under different conditions (e.g., different activity types, different times of day). They then evaluated those trial records in their historical records until they had found a preferable activity or a preferable time. During this practice, participants treated their historical records as a source to reflect on their trials.

For participants who did not exercise regularly before this study, it was difficult for them to find preferable conditions for performing physical exercise (e.g., find a preferable exercise, find a preferable time, etc.). When P13_{II} discussed her experience in the first phase of the study, she mentioned that it was hard for her to find a preferable exercise to do: "*Probably picking what to do is the hardest part [...] it's just a question of what I want to do, what do I think I feel like doing.*" To figure out a preferable exercise, P13_{III} had several trials of planning different activities (P). During this practice, she consciously paid attention to the subjective feedback from doing those experiences (P): "*I see here there are a lot of trials and errors that I did over these past two weeks or these past four weeks [...]. The first week was kind of rushing into doing [different] things without really considering [...]. I kind of jumped around during the first week, and that was a trial week. [During that week] I was trying more things, [and trying to see which activity is] going to be better for me or make me feel better.*"

By planning physical exercise under different conditions (e.g., different times of day and different exercises), and referring to those records in the historical planning data, participants gained a better understanding of their capabilities and were able to identify preferable conditions for performing physical exercise. P5_{III} would first plan the exercise that she thought would work for her and then reflect on her historical planning records to see if that was really the case (P): "*[If] I'm noticing that I was missing a lot of exercises before and just seeing that like Okay, so I thought this [exercise] would work, but I keep missing them, so it's not working, so I need to do something different.*" P13_{III} used the records on the calendar view (Fig 6 (D)) to recall her experience of performing different exercises (P). In this

way, P13_{III} could identify a suitable activity and plan that more: “*I can look back at this [the calendar view] and remember that Oh, I did this [exercise] one week and that [exercise] didn’t really work for me, but I performed this activity much better, so I can take that and move forward.*” P12_{III} performed different activities during the first few weeks and used the historical records on the calendar view to reflect on her capabilities (P). In her later planning, she narrowed down the activity to the most effective one: “*Looking at my previous record helps me to gauge my own strengths or capabilities and then helps me in planning that activity accordingly [...] In the previous week, I was kind of planning different activities [...] [until] I felt that [doing workout] was the most effective activity. [...] That’s why I switched to one activity [doing workout] that I like most.*”

5 DISCUSSION

This study explored people’s planning for regular physical activity and the impact of historical records on their planning behavior. We found several factors (e.g., routines, anticipated energy level, and past experience of performing physical activity) that were helpful for plan creation. We also identified several barriers that impact people’s plan execution, including being disrupted by unexpected events, being affected by temporally adjacent events, and being physically or mentally tired. We further found that historical planning records could potentially help people avoid unexpected events by helping them identify the likelihood of being disrupted, reduce the impact from temporally adjacent events by rearranging schedules, and determine preferable planning conditions by reflecting on trial records. In this section, we revisit our findings and discuss opportunities for future research.

5.1 Factors that Support Plan Creation

Prior literature shows that having a routine helps people complete repetitive activities [44, 46, 55]. This study adds to the prior work by demonstrating that having a schedule or routine helps participants better anticipate future exercise opportunities. Banovic et al. demonstrated that a tool could extract and model users’ routines based on data representing people’s previous activities [9]. Davidoff et al. proposed to augment the calendar with routine information to help users avoid conflicts in their schedules [18]. Similar methods could be applied to physical activity planning tools to assist people in identifying future exercise opportunities.

This study shows that people would consider their anticipated energy level when planning future activities. Still, it is unclear how people anticipate the energy consumption of different activities. There might be gaps between a person’s perception and real body condition (e.g., underestimating the energy consumption of one exercise may cause exhaustion). This calls for future studies to better understand how people perceive the energy consumption of different activities and apply that understanding to their planning.

Finally, the study indicates that participants can use their past experiences to inform future planning, even without historical records presented. This finding sheds light on the potential value of using historical records to assist people’s planning.

5.2 Support People’s Sensemaking with Historical Records

It has been previously shown that people could make sense of their behavior by looking at their data [1] and identifying their patterns

and trends [39, 59]. Our study contributes to the understanding of how people can make sense of their historical planning records.

5.2.1 Presenting Information around Failure Records. We found that people tend to pay attention to their failure records when presented with color-coded historical records, which was also observed in the LifelogExplorer study [35]. This implies that the failure records can serve as an entry point for people to interpret their data. When designing a physical exercise planning tool with historical data, designers may consider presenting important data (e.g., contextual factors, subjective perception, etc.) around the failure records, so users can quickly perceive the information around their failure records, especially when users are overwhelmed by different kinds of information presented [13].

5.2.2 Designing to Address Extreme Values in Historical Records. Choe et al. showed that the extreme value in an individual’s data can quickly catch their attention, causing further reflection [13]. Our study confirms this claim by showing that people also tended to pay attention to the group of records with a much higher completion rate or larger number of plans. In this regard, a planning tool could consider highlighting the group of records with extreme values as a way to catch users’ attention and drive them to reflect on planning data.

5.2.3 Designing to Support Grouping Similar Records. Li et al. found that people could draw connections between physical activity and contextual information [40]. Our findings further show that participants can group their records by common contextual factors (e.g., days of the week, time-of-day, type of exercise) and are able to evaluate similar failure records as a whole. This confirms the importance of presenting users with contextual factors in their plan creation [46]. Though we help summarize users’ records on the historical summary view, we find that the calendar view can also help users group their records around different days of the week and activity types. Designs to support users to group data from different dimensions, as a way to help users capture trends in their data and avoid information explosion [35], might be considered when designing a system that presents people’s historical records with multiple contextual factors.

5.3 Support Developing Planning Strategies with Historical Records

Prior work investigated ways (e.g., text message intervention [43], mobility pattern visualization [64, 65], and crowdsourcing [2, 3]) to support people’s action planning for physical activity. Our study shows that historical records can contribute to individuals’ plan quality. Moreover, we demonstrate that historical records can help individuals deal with barriers in plan execution.

To form a valid implementation intention that connects anticipated situations (i.e., when, where) with the intended action (i.e., what, how) [25], individuals’ plans need to be precise [19, 65] and viable [20, 65]. Findings from our study suggest that historical records could help people specify both the anticipated situation and the intended behavior, thus contributing to the plans’ viability and specificity. By reflecting on historical planning records, people can

plan physical activity during the period that they are less likely to be disrupted, thus narrowing down the anticipated situations and forming precise conditions in their planning. Findings also show that people can use historical records to reflect on their trials and better understand their capability of performing physical activity under different planning conditions (i.e., what activity to perform and what time works best for them), thus creating viable plans that reflect their capabilities. In this regard, planning with historical records can potentially benefit the quality of people's plans regarding specificity and viability, thus helping people form effective implementation intentions. Future studies may want to further examine historical planning records as a factor when trying to understand people's planning behavior and the formation of implementation intention.

Still, forming a viable plan doesn't necessarily lead to successful execution. Individuals' plans are vulnerable to being disrupted when facing the challenges (e.g., unexpected events [46], affected by temporally adjacent events, and physical and mental tiredness) in their plan execution. While previous research mostly focused on improving plan quality, it remains unclear how individuals deal with barriers to plan execution. In this study, we demonstrate that people can leverage their historical planning records to derive insights regarding those barriers and apply that knowledge when creating plans. In other words, historical records not only help improve individuals' plan quality, but also reduce the risk of being affected by the barriers in plan execution. With historical records presented, individuals can reduce the likelihood of being disrupted by unexpected events, reduce the risk of being disrupted by temporally adjacent events, and better understand their abilities to perform exercises under different conditions. In this section, we discuss how future designs can better support those practices.

5.3.1 Designing to Support Identifying the Likelihood of Being Disrupted. Unexpected events are impromptu events that are hard to be taken into consideration in individuals' planning and can occur at any moment, causing challenges for individuals to successfully execute their plans. Though Paruthi et al. has shown that it is difficult for people to foresee unexpected events in plan creation [46], we demonstrate that historical records can potentially reveal insights regarding the likelihood of being disrupted, thus helping people avoid unexpected events by planning under situations that are less likely to be disrupted. Future designs of a planning tool could consider supporting people to identify the likelihood of being disrupted in their schedules. Eagle et al. proposed to model the predictable structure of an individual's life [21]. And Joslyn et al. suggested presenting the anticipated likelihood of being disrupted within particular situations using numeric values [31]. With a larger number of historical planning records, similar approaches could be used to model the likelihood of being disrupted by learning from users' historical planning records. For example, a tool could dynamically present users with the value that represents the likelihood of being disrupted when they are specifying planning conditions.

5.3.2 Designing to Support People Reduce the Impact from Temporally Adjacent Events. Our findings show that a planned exercise can be affected by its temporally adjacent events. Those deviations from routines could cause failures when executing the plans [17, 18]. In this study, we found that historical records could support

individuals to rearrange their schedules to minimize the impact of temporally adjacent events. By reflecting on historical records (especially the failure records) with other calendar events, individuals derived insights regarding how their plans were affected by temporally adjacent events. With this knowledge, individuals could avoid planning before or after the events with a higher risk of deviations and identify the "sweet spot" [46] that involved fewer distractions on their schedule. This potentially helps individuals develop physical activity routines that they can maintain in the long run. Davidoff et al. used machine learning as a way to predict deviations from people's routines [17]. A similar approach can be used to help predict the likelihood of executing the planned exercise after a sequence of activities. Thus, a planning tool can suggest the likelihood of plan execution after different calendar events to assist people's plan creation.

5.3.3 Designing to Support People's Reflection on the Trials. Our study shows that people with little experience of performing regular physical activities face challenges in creating plans tailored to their physical capability. A less tailored plan adds to the risk of execution failure and might cause harm to the individual's body (e.g., overdoing the activity). With historical records presented, we found that people could reflect on their trial records to determine a preferable planning condition (e.g., preferred exercise to do, preferred time). To identify a preferable condition, individuals would first try planning physical activity under different conditions and then evaluate those trial records. Since people have different preferences and capabilities for performing physical exercise, supporting users to carry out self-experimentation by referring to historical planning records seems to be a feasible way for users to better understand the suitable conditions that matter to them [14]. Future planning tools may leverage self-experimentation frameworks [32] to support users' practice of tracking and reflecting on their trials. For example, a planning tool could allow users to label the exercise that they want to try, so they can self-experiment with the variable (e.g., activity type, duration, time) in the planning conditions and work out the most suitable one by evaluating the outcome (e.g., completion status, body feeling, satisfaction).

5.4 LIMITATION

The study results might not fully represent real-life situations due to the exploratory nature of the study. The participants in this study were asked to plan physical activities at a relatively high frequency (at least 4 times a week) over a short (28 days) period. During the study, the participants were aware of participating in a study and being observed, making them more likely to stick to their plans. The participants became less motivated in the second phase of the study, causing them to make fewer plans. However, this study was designed to be an exploratory study aimed at understanding how people leverage their historical planning records to inform their future planning. The empirical evidence from this study provided insights into people's plan creation and execution and the potential effects of historical records on people's planning behaviors. Future work may want to evaluate the possibility of incorporating historical planning records into a long-term planning intervention and quantitatively evaluate the result by looking at their plans' completion rates.

Also, the types of participants were limited in this study. Findings from the study may not apply to a broader population. For all the 17 participants who completed the study, there was only one male. Concerning the potential harm caused by regular physical activity, we didn't include elderly people (over 55) and people with health issues related to physical activity. As a result, all participants were either current university students or recent graduates; the way they organized their daily schedule might be different from people with years of working experience. Participants in this study also had prior experience with digital planning tools, such as Google Calendar. Future work might want to evaluate the people's planning experience and the effect of historical planning records with a diverse population (e.g., middle-aged and older adults [69]).

6 CONCLUSION

This paper examined people's planning experiences in the wild and the impact of historical records on their planning behaviors. Our findings articulate useful factors in people's plan creation and the barriers in plan execution. We demonstrate that people are able to reflect on their historical planning records and derive insights to inform future planning. This paper extends the previous discussion on supporting physical activity planning and contributes to an understanding of the effect of the historical planning records. This work suggests future research opportunities for supporting people's planning for regular physical activity.

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