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Understanding pivotal experiences in behavior change for the design of technologies for personal wellbeing

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ABSTRACT

Most health technologies are designed to support people who have already decided to work toward better health. Thus, there remains an opportunity to design technologies to help motivate people who have not yet decided to make a change. Understanding the experiences of people who have already started to make a health behavior change and how they made a pivotal decision can be useful in understanding how to design such tools. In this paper, we describe results from data collected in 2 phases. Phase 1 consisted of 127 surveys and 13 interviews with adults who have already accomplished behavior change(s). Phase 2 consisted of 117 surveys and 12 interviews with adults who have either already accomplished their behavior change(s) or are currently working toward them. We identified four factors that lead to pivotal experiences: (1) prolonged discontent and desire to change, (2) significant changes that increase fear or hope of future, (3) increased understanding of one's behavior and personal data, and (4) social accountability. We also describe a design space for designing technology-based interventions for encouraging people to decide to make a change to improve their health. Based on feedback from participants, we discuss opportunities for further exploration of the design space for people who are not yet motivated to change and for ethical considerations for this type of intervention.

1. Introduction

Making the decision to change one's behavior toward good health can be life-altering. For those who have engaged in unhealthy behaviors for years or even decades, this decision can be difficult and emotional, yet necessary for an improved quality of life. Support through this process can help these people achieve success in changing their behaviors [5]. Recognizing the difficulties inherent to achieving and maintaining a change in behavior, many technologists have designed tools to support people in successfully changing a variety of behaviors, including eating better [24], exercising more [13], quitting smoking [3], and improving sleep behaviors [6]. Most of these tools have been designed to provide support after people have decided to make a change. Thus, there remains an opportunity to design new tools to help people make that initial decision and then support them through that process toward eventual success.

To design for those who have not yet made the decision to change, designers and HCI researchers need to understand the factors that lead to a person's decision and what factors were pivotal for an individual to carry through with the change for their personal wellbeing. Psychological theories for behavior change [20,17,26,40,49] describe intrinsic and extrinsic motivations for why and how people make changes for their personal wellbeing. Long-term behavior change, however, is not a linear process and most people move between relapses and some even give up [50]. Following a review of related work, Chilton conceptualizes the potential for specific moment of "epiphany" in the behavior change and characteristic antecedents and consequences experiences that define the moment. We build on Chilton's conceptualization to gather empirical evidence on whether there are specific moments that cause people to decide to change their behavior and/or follow through with it? We refer to this moment as a *pivotal moment* and the experiences in that moment as *pivotal experiences*. Research to understand the role of pivotal experiences in the process of behavior change can help guide development of technologies that prompt pivotal moments or support people during pivotal experiences. With the increase in number of behavior change technologies, we also sought to understand what is the role of technology in the moment (if any) and can technology be antecedent factor to pivotal moments?

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To understand the role of pivotal experiences in behavior change, we studied experiences of people who have already decided to make changes for their personal wellbeing. In this study, we conducted surveys with people who have decided to make a change for their personal wellbeing and follow up interviews with adults who have either accomplished changes in their behavior or were currently working toward them. We conducted this study in two phases: Phase 1 consisted of 127 survey responses and 13 interviews and Phase 2 consisted of 117 survey responses and 12 follow up interviews with adults who have decided to make a change for a better lifestyle. We analyzed these surveys and interviews to understand what led people to decide to make a change and to determine whether their process included a moment that they considered pivotal for that decision. Examining the role of technology in these moments, we found that technology led to a pivotal moment only for 3 participants, but people often used it to access support in the moment or right after a pivotal experience.

Based on these results and prior research, we derived a design space for *catalyzing pivotal moments for people who are not yet motivated to change*, from which developed three storyboard narratives depicting ideal scenarios of how technology might induce pivotal experiences for individuals who are not motivated to change a specific behavior. We used these design sketches to elicit feedback from the 12 interview participants in Phase 2. We discuss opportunities for the persuasive technology design and research communities to continue to explore how the design space can be used to explore technologies that can motivate people who are not yet motivated to change and extend the discussion on ethical considerations for this type of technology designed to manipulate a person's understanding of personal wellbeing and their agency in deciding to change.

In this study, our primary contributions are:

1. an empirical analysis of pivotal experiences in behavior change for personal wellbeing; and
2. development of a design space for developing technologies to catalyze pivotal experiences for those not yet motivated to change.

2. Related work

Our research was guided by existing theories of behavior change, which informed our inquiry into pivotal moments, and research on persuasive design, which led us to explore the role of technology in the design of interventions for individuals who are not yet motivated to change.

In this research, we focus on experiences that were recognized and considered pivotal by people making behavior changes. These experiences were primarily conscious decisions, though behaviors may also be influenced through subconscious processes such as subliminal changes (e.g., [9]), nudges [44] or habits and their triggers [2].

2.1. Defining a pivotal moment

A pivotal moment in behavior change can be understood through the metaphor of having an "epiphany." Chilton [10] describes three characteristics that define an epiphany moment in behavior change – (1) Sudden, unplanned clarity, (2) Ability to choose a path, (3) Confidence and resolve to move forward. In our work, we chose to refer to these as pivotal moment because having an "epiphany" may only be characterized as spiritual in nature for some. Building on Chilton's conceptualization, we define a *pivotal moment* in behavior change as the time when a person decides to adopt new behavior(s) for their personal wellbeing and/or becomes ready to make progress toward positive change. Although we used this to conceptually guide our work, we purposefully did not pre-define what we meant by pivotal moments to study participants. We asked them open-ended questions, as we wanted to inductively analyze participants' perceptions of what constituted a pivotal moment for them.

2.2. Theories of behavior change

Covering the vast literature on behavior change theories and techniques is beyond the scope for this paper. Our research questions focus on understanding pivotal moments and designing for people who are not yet motivated to change. To that end, we summarize how the above three characteristics of pivotal moments [10] can be explained through the lens of relevant psychological theories of motivation and health promotion. We also review stage-based models for an overview of the longitudinal process of behavior change.

2.2.1. Stages of behavior change

Where a person is in their behavior change process can be characterized by two stage-based models: the Transtheoretical Model of Behavior Change (TTM) [40] and the Precaution Adoption Process Model (PAPM) [49]. The Transtheoretical Model defines stages of *precontemplation*, *contemplation*, *preparation*, *action*, and *maintenance*, while the Precaution Adoption Process Model includes the stages *unaware of issue*, *unengaged by issue*, *deciding about acting*, *decided to act*, *acting*, and *maintenance*. The process of change, however, is not linear: different individuals may spend different amount of times in different stages, skip stages, or and move through multiple stages simultaneously [50]. Therefore, we chose not to use the framing of using specific time intervals to define stages—such as within 30 days or 6 months—as used to define stages in Transtheoretical model.

The stages in these models are also helpful to conceptualize what it means to not yet be motivated to change. Not being motivated to change could mean that a person is in the pre-contemplation state, either unaware that their behavior is unhealthy or that it is possible to change, that they are unengaged by the issue, they are undecided if they want to change, or they relapsed during acting and are not motivated to try again (e.g., they have "given up"). Building off the stage-based models, we distill four categories of people who have decided to change: people who have (1) decided but are not currently acting toward change, (2) decided and are taking at least one action toward change, (3) decided to and believe that they accomplished change, and (4) decided to, relapsed, and are not currently working toward change or have not succeeded. In this research, we wanted to explore whether pivotal experiences catalyze the progression of a person through these stages and, if so, what trajectories they take. To understand when pivotal moments occur and the types of transitions they lead to in the behavior change process (e.g., *unaware* to *aware*, or *unaware* to *making decision* or *decision to act*), we ask the following research question:

> **Research Question 1 (RQ1):** When are pivotal experiences manifested in the process of behavior change for personal wellbeing?

2.2.2. Factors that catalyze behavior change

Health promotion theories describe factors that may catalyze factors that can be pivotal for the change. The Health Belief Model [26] describes a person's likelihood to change their health behavior and adopt health services as a consequence of perceived susceptibility, severity, benefits, and barriers. It also specifies potentially pivotal cues to action that can modify these perceptions, which can be either internal (e.g., pain) or external (e.g., information from others or events). While making benefits, risks, and severity explicit can increase a person's resolve to change, specific moments that help in understanding and removal of barriers can increase one's ability to change and provide clarity on steps to take.

According to Cognitive Dissonance Theory [20], when people's actions are inconsistent with their perceived image of themselves, they feel discomfort and try to take actions to minimize this discomfort using various strategies. We speculate that a pivotal experience of increased resolve may occur when this feeling of discomfort reaches a threshold that motivates the person to start changing their behavior. However, people may also resolve this discomfort by modifying their perception

of themselves, which may result in the individual not taking any action. Encountering and maintaining social perceptions and norms beyond one's control can also be a driving factor. In his theory of Presentation of Self in Everyday Life, Goffman [23] wrote that a person presents themselves how they desire others to see them on their "front stage" while maintaining a "back stage" that only themselves or those closest to them see. A pivotal moment might occur when a person's front and back stages cross-over or conflict, sparking motivation to change.

Self-Determination Theory [17] also explains how individual and social factors together drive psychological motivation for human behavior. These factors include competence (i.e., sense of control or mastery over the environment), relatedness (i.e., sense of belonging and being connected to other people), and autonomy (i.e., agency of acting out of one's own interests and values). The lack of and desire to achieve one or more of these psychological needs can constitute pivotal experiences. Chilton [10, p. 18] also describes antecedents that can be precursors to epiphanies, such as a long time of emotional chaos, being unhappy, desperation, exposure to a message of hope, or a sense of stagnation or wandering aimlessly. Chilton recommends exploring the potential for positive impact and ethical implications of inducing epiphanies for behavior change in the field of Nursing, which can also extend to research in persuasive design. To understand if these factors are considered a part of the pivotal experience, if there are additional factors that constitute a pivotal experience, and role of technology in pivotal moments, we ask the following research question:

Research Question 2 (RQ2): What factors lead to pivotal experiences in making progress toward behavior change? Specifically, we seek to answer the following sub-questions for RQ2:

1. *How are pivotal experiences different from experiences that are not considered pivotal?*
2. *What is the role of technology in supporting changes during pivotal experiences?*

2.3. Persuasive design

Fogg [21] explains that optimizing three factors—motivation, ability, and trigger—at the same time can nudge someone to act on a "target behavior." Triggers can increase ability (facilitator), increase motivation (spark), or be reminder to perform a certain behavior (signal trigger). Oinas-Kukkonen & Harjumaa's Persuasive Systems Design framework [37] describes four groups of design principles, including (1) primary task, (2) dialogue, (3) system credibility, and (4) social support. We focused on incorporating design principles from groups 1, 2, and 4. For example, we incorporate reduction, personalization, and self-monitoring from group 1, reminders and suggestion from group 2, and social comparison, normative influence, social facilitation, and competition from group 4. Abraham et al. [1] provide a list of 26 behavior change techniques (BCTs) and a taxonomy to summarize behavior change theories. For example, prompting barrier identification is a technique where one asks a person to identify barriers to their change so they can plan ways to overcome them. Together, these principles and techniques informed the development and analysis of our design space and our ideation of example applications. We aimed to understand whether certain persuasive design strategies are more common in pivotal moments or more likely to catalyze pivotal moments.

2.6. Existing behavior change technology

The digital health and human–computer interaction (HCI) communities have designed many technologies to promote behavior change, including technologies to promote physical activity [13], improve nutrition [24], improve sleep [5], manage stress [34], or quit smoking [3]. Additionally, myriad commercial products exist to promote health behavior changes, including for physical activity (e.g., Fitbit, Garmin, Wii Fit, Zombies Run, Nike+), sleep (e.g., Fitbit), healthy eating (e.g., MyFitnessPal, peer support forums, LoseIt), and smoking cessation (e.g., QuitNet.com). These technologies have varied success [32], but they are often most successful for individuals already motivated to change their behavior. Many public health promotion campaigns are delivered through technology to target people through more engaging and interactive mediums. Technology is also effective in reaching people who face barriers such as cost, time, and stigma in accessing health care services [30,36,51]. Research is needed to understand what features of technology can be pivotal for people who have not yet decided to change their behavior.

In addition to designing novel health applications, the digital health community has engaged in an important discussion of health technologies. These discussions include how to evaluate health behavior change technologies [29] and how enjoyable consumer health technologies might be a gateway to engaging in more effective health activities [42]. The HCI research community has also sought to understand the ethical and socio-cultural implications and long-term impact of these behavior change technologies [41]. To date, research has focused on technologies that support behavior change or on health promotion campaigns. But do other technologies–those not explicitly designed for health promotion–lead to pivotal experiences? How should designers consider this? There is also an opportunity to design technologies that better support people as and immediately after they have a pivotal moment, but doing so requires an in-depth understanding of how technologies and other events can cause them, and what people's needs are when they have them. This leads us to our final research question for this work, which is:

Research Question 3 (RQ3): How can technology catalyze pivotal experiences for people who are not yet motivated to change?

3. Methods

To better understand pivotal experiences in behavior change, we conducted surveys and follow-up interviews with adults who have already decided to change their behavior. We conducted an initial set of surveys and interviews in Phase 1 that we used to develop a framework for design space and to iterate on and conduct a second round of surveys and interviews in Phase 2 (see Appendix B, for survey and interview questions). Our study follows a mixed methods approach [27] and we aimed to recruit people with a wide variety of experiences. We summarize the study procedures in Fig. 1. This study was approved by the Human Subjects Division of University of Washington.

3.1. Phase 1: Initial survey and interviews

We first conducted surveys and interviews to understand catalysts that motivate people to change a health behavior and how technology can be designed to catalyze change. We recruited people who believed they have accomplished a health-related behavior change via surveys

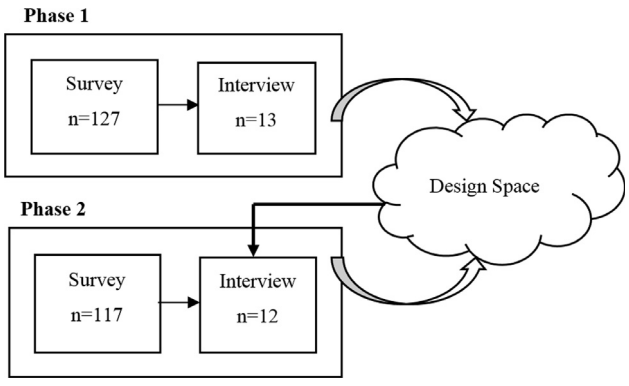


Fig. 1. Overview of study procedures and iteration of the design space.

Table 1
Demographic distribution of participants of survey in Phase 1.

Gender	Female (70%), Male: (26%), Other (2%), Did not disclose (2%)
Age	18–29 years (44%), 30–39 years (29%), 40–49 years (12%), 50–59 years (10%), 60–69 years (3%), 70 + years (1%), Did not disclose (1%)
Region	USA: 20, Belgium, China, Czech Republic, Germany, India, Ireland, Israel, New Zealand, Taiwan, UK
Income	Less than $25k (15%), $25k–50k (22%), $50k–$75k (16%), $75–$100k (10%), $100k–$150k (17%), $150–$200k (3%), $200k + (5%), No response (12%)
Education	Doctorate Degree (14%), Master's Degree (26%), Bachelor's Degree (21%), Some college (26%), High school Diploma (1%), Professional degree (2%), Did not answer (1%)
Field of work	Administrator, Attorney, Caregiver, Chef, Counselor, Customer Service, Designer, Engineer, Finance Manager, IT Manager, Professor, Researcher, Social Worker, Self-employed, Student, Teacher, Unemployed, Writer

on social media network of researchers, craigslist and online communities such as eHealth forum and livestrong.com. Participants were asked to select one behavior per survey response. Questions in the survey asked participants to describe the moment they decided to make their behavior change, what factors led to that moment, who was involved in helping them make the change, steps they took after the moment, and how they felt about making the change. The survey consisted of 17 questions and took around 10 min to complete. Participants could optionally provide their contact information to enter a drawing for $50 gift card. Additionally, they could indicate their willingness to be contacted for a follow-up interview. We received 126 complete responses (referred to as PS#) and demographic details of survey participants are presented in Table 1.

From the survey respondents who agreed to be contacted for follow-up interviews, we selectively sampled participants and conducted interviews with 13 participants. Members of research team read all survey responses and selectively sampled participants who indicated having a distinct moment when they made a decision for behavior change and also strived to sample across different behavior changes (e.g.; physical activity, quitting smoking) and diverse demographics. During the interview, we asked participants to elaborate on the moment they made their decision to change, factors that led to the moment, and whether they had other significant events while making the change and how they were different. All interviews were conducted over Skype or phone and lasted between 30 and 90 min. Participants received a $25 gift card after completing the interview. All data from the survey and follow-up interviews were collected in 2012. Details of participants in Phase 1 interviews (referred to as PI#) are presented in Table 2. All participants had accomplished their change (3 Males, 10 Females).

3.2. Phase 2: Revised survey and interviews

Informed by preliminary findings from Phase 1, we (1) derived a design space to envision technologies for catalyzing pivotal experiences for individuals who are not motivated to change, and (2) iterated on the survey and interview protocols used in Phase 1. In Phase 2 interviews, we presented participants with three narratives in storyboard form, representing different dimensions within the design space, and asked participants feedback and reactions to the different design ideas. Our goal was not to present novel designs; we instead sought to elicit reactions to various possible designs, including some inspired by existing technologies. Data for Phase 2 was collected between September 2016 and February 2017. There was a four-year time gap between phase 1 and phase 2. During that time, new members joined the research team, reviewed the analysis of phase 1, and brought new perspectives to phase 2.

3.2.1. Phase 2 survey

We revised the survey questions to make the inquiry about pivotal moments explicit to participants. We also asked an open-ended question on the timing of the pivotal moment – "do you believe you had a pivotal moment while making the change?" – instead of centering on decision making. We added questions that asked participants about technologies they used during and after their pivotal moment (if any), barriers they faced in making their change (if any), and how they overcame those barriers. We included all adult participants who decided to change and categorized them, based on self-report, as individuals who (1) accomplished a change (SA#), (2) are currently working toward a change and have taken at least one action toward it (SC#), (3) decided to change but have not started working toward it (SN#), or (4) made a decision to change but did not succeed (SD#). All participants in categories 3 and 4 were asked if they intend to act toward their change in future and all reported yes. For individuals who did not believe they had a pivotal moment, we asked them to describe the time they made their decision to change. Participants were given the option to select multiple behaviors, and were requested to select the behaviors they decided to change "at the same time".

We recruited participants who were 18 years of age and above and who self-reported they had decided to change their behavior for personal wellbeing. We sought to recruit participants from a variety of online communities for health-related behavior change and reached out to moderators and site admins to request permission to post. We posted our recruitment advertisement inviting people who have "ever decided to make a behavior change for personal wellbeing" and are 18 years of age and above to complete the survey. The sites we recruited from included the social media networks of researchers, Reddit.com forums on

Table 2
Details of participants of interview in Phase 1.

Participant ID	Behavior change(s)	Time since change (range)	Occupation	Age range (years)
PI01	Exercise	6–12 months	Graduate Education	18–29
PI02	Quit drinking	1–2 years	Retail Assistant Manager	30–39
PI03	Exercise	Less than 6 months	Student	18–29
PI04	Exercise	Less than 6 months	Sales Specialist	18–29
PI05	Weight loss	6–12 months	Social Worker	18–29
PI06	Weight loss	6–9 years	Dean	50–59
PI07	Weight loss	1–2 years	Aerospace Engineer	30–39
PI08	Diet change	3–5 years	Medical Student	18–29
PI09	Quit drinking	3–5 years	Executive Assistant	30–39
PI10	Quit smoking	More than 15 years	Comm. Ed. Coordinator	60–69
PI11	Quit drinking	3–5 years	Retired	50–59
PI12	Quit drinking	10–15 years	Chef	40–49
PI13	Weight loss	10–15 years	Retired Teacher	60–69

Table 3
Demographic distribution of participants of survey in Phase 2.

Gender	Female: 85 (73%), Male: 29 (25%), Non-binary: 1, Did not disclose: 2
Age	18–20 years: 9, 20–30 years: 60, 30–40 years: 24. 40–50 years: 11, 50–60 years: 5, 60–65 years: 4, Did not disclose: 4
Race or Ethnicity	White: 84, Asian: 19, Native Hawaiian or pacific islander: 1, Black 2, Middle Eastern: 1, Mixed race: 2, did not disclose: 2
Region	Rural: 5, Sub-urban: 39, Urban: 69; USA: 103, Canada: 4, UK: 1, Malaysia: 1, China: 1, South Africa: 1, Australia: 2, Finland: 1, France: 1, Ireland: 1, Philippines: 1
Income	$150k and above: 5, $149k–$20k: 77, less than $20k: 31, Did not answer: 4
Education	Post graduate: 2, Doctorate: 6, Graduate: 18, Bachelor's Degree: 39, Some college: 32, High school: 10, Professional degree: 3 other: 5, Did not answer: 2
Field of work	Students: 34, Industry professionals: 30, teaching/academia: 7, retail: 5, Unemployed: 11, Other: 25, No answer: 2; Other includes retired, stay at home parent, government and administrative posts, assembly line, Healthcare, pharmacy, security, Freelance, marketing, graphic design.

Table 4
Demographic distribution of participants of interview in Phase 2.

Gender	Female: 8 (66%), Male: 4 (33%)
Age	Range: 21–57 years 20–30 years: 6, 30–40 years: 4, 40–50 years: 1, 50–60 years: 1, Average = 32.99 (Stand. dev. 10.79)
Race / Ethnicity	White: 9, Asian: 1, Middle Eastern: 1, Black: 1, no Hispanic
Region	US: Washington: 9, Kansas: 1; South Africa: 1, UK: 1 Rural: 2, Sub-urban: 3; Urban: 7
Income	$150k or more: 1, $149.9k to $100k: 2, $99.9 to $75k: 1, $74.9 to $50k: 2, $49.9k to $35k: 2, $34.9 to $20k: 2, less than $20k: 2
Education	Doctorate Degree: 3, Graduate Education: 2, College Education (Bachelor's): 2, College with a Diploma: 1, Some College Education: 3, High School Degree or Equivalent: 1
Field of work	Industry professionals: 4, Teaching or Academia: 2, Student: 1, Unemployed or seeking employment: 1, Others: 4 (assembly line, freelance camera operator, rowing coach, chronic illness)

behavior change (including subreddits /habbitdesign, /fitness, /behaviorchangetech, /behaviorchange, and /selfimprovement), online communities such as eHealth forum and whyquit.com, and a university-affiliated recruitment site hosted on the Institute of Translational Health Sciences (ITHS). We did not recruit using any offline methods other than posting a flyer at a café, and our data is thus biased toward people who are current users of online social platforms. The survey took approximately 25 min to complete; participants could optionally provide contact information to be entered in a drawing for a $50 gift card drawing and could volunteer for a follow up interview.

We received 175 non-duplicate survey responses. Eight responses were deleted as they were under 1 min and 4 were ineligible (1 did not consent and 3 did not decide to make a behavior change). Of the remaining 163, 117 were eligible and complete (45 responses were incomplete, 1 was troll response). Respondents took an average time of 13 m and 55 s to complete the survey, with a range between 3 min and 1 h. Demographic questions were optional for participants, and a demographic breakdown for those who chose to respond is shown in Table 3. We note that our respondents are skewed toward female participants and people who are between 20 and 30 years old. 57 participants responded through Facebook, 24 participants responded through Reddit. We speculate that recruiting primarily through online platforms skewed our sample toward younger people. We also note that the participation rates of males are typically less in behavior change studies [38], which may explain the bias toward female respondents.

Participants reported changing 29 different types of behaviors, 11 of which we suggested as options and 18 of which were self-reported by participants as other: increasing physical activity (68.3%), changed their diet (47%) losing weight (41.8%), improving sleep (35%), improving financial wellbeing (27.3%), improving social life (25.6%), quitting smoking (19.6%), quitting drinking (16.2%), quitting drug use (5.1%), gaining weight (4.2%), and other (15.3%, such as reducing caffeine intake, enjoying life more, seeking help for mental health). Participants changed from 1 to 8 behaviors at the same time (median = 3 behaviors at the same time, 33.3%). Average time since participants accomplished their change was 5 years and 3 months (min = 2 months, max = 24 years). At the time of the survey, time since decision to change ranged from 2 weeks to 5 years for participants who had decided but were not acting on the change (the 5-year gap was after relapsing while quitting smoking) and 1 week to 10 years for those who did not succeed, while all participants in these two categories wanted to work on their change in future.

3.2.2. Phase 2 interviews

For follow up interviews, we selectively sampled from phase 2 survey respondents who agreed to be interviewed, who believed they had pivotal experiences, and who were either currently working toward the change or had accomplished the change. In the first part of our phase 2 follow-up interviews, we asked participants to elaborate on their change, how their behavior affected their daily life before the change, to describe the pivotal moment and factors that led to it, how they currently feel after the change, other events such as barriers experienced and overcoming them, what might have helped them make the change earlier (if anything), and advice for others who are not yet motivated to change a behavior. In the second part of the interview, we asked participants for their feedback on what they liked and/or disliked about the three storyboard narratives based on the design space. We discussed with participants which of these features they liked best and why and to envision how to improve the design for people who are not motivated to change their behavior. To further refine our design space and design ideas, we sought to elicit feedback from people who have experienced pivotal moments. We interviewed 12 participants, who we refer to as IC# if they were currently working on the change(s) and IA# if they accomplished the change(s) (Tables 4 and 5).

Each interview was conducted by two members of the team and lasted for approximately 40–60 min. All participants were compensated $30 for their time. Seven of these interviews were conducted over the phone, three in person, and two over Skype. With participant consent, all interviews were audio-recorded. All audio-recordings were transcribed except for participant I05's recording, which was incomprehensible due to technical issues. For this participant, we referred to notes taken during the interview.

Interview participants in Phase 2, changed a range of nine different behaviors, seven having accomplished their change and five currently working toward a change (Table 5). At the time of interview, IA04 already quit drinking but was working toward quitting smoking and IC12 was working toward the other six behaviors listed in Table 5, but had already quit drinking.

Table 5
List of participants of interview in Phase 2 and the behaviors they changed.

Participant ID	Behavior change(s)	Stage of change	Time since decision to change[a]	Age (years)
IA01	Lose weight, increase physical activity	Accomplished change	7 years	57
IC02	Lose weight, increase physical activity, change in diet	Currently working	5 months	23
IC03	Lose weight, increase physical activity	Currently working	2 years	28
IC04	Change in diet, quit drinking alcohol, improve sleep	Currently working	2 months, 3 weeks	34
IA05	Quit smoking	Accomplished change	18 weeks	49
IA06	Lose weight, increase physical activity, change in diet, quit alcohol	Accomplished change	4 years	27
IA07	Increase physical activity, improve sleep	Accomplished change	6 years, 5 months	30
IA08	Quit smoking	Accomplished change	2 years	34
IC09	Losing weight, increase physical activity, financial wellbeing, socializing	Currently working	1 month	24
IA10	Increase physical activity	Accomplished change	1 year	29
IA11	Quit drinking alcohol	Accomplished change	3 years, 1 month, 1 week	21
IC12	Increase physical activity, quit smoking, quit drugs (prescribed medication), improve sleep, financial wellbeing, socializing	Currently working	1 month 3 weeks	39

[a] Time since change was reported by participants when they took the survey (November 2016–February 2017).

3.3. Data analysis

To answer **Research Question 1** (*RQ1: When are pivotal experiences manifested in the process of behavior change for personal wellbeing?*), we represented the data from all 25 interviews in Phases 1 and 2 into timelines as events described by the participant arranged in chronological order. We marked the events that participants believed to be pivotal and other event markers such as barriers to change or ability to change. We then arranged the timelines across different participants and segmented them as unaware of the change, making the decision to change, acting toward the change, and relapsing.

To answer **Research Question 2** (*RQ2: What factors lead to pivotal experiences in making progress toward behavior change?*), we qualitatively analyzed survey and interview data from both phases. We first inductively coded of 35 survey responses from Phase 2 and created affinity diagrams [25]. For interviews, we (AB, SK, ME, MC) first created a coding library by independently coding 6 interviews inductively and defined each code (see Appendix C, Table C.2, for final coding library). Researchers who did not conduct the interview coded the interview and then shared memos. We then used this coding library to code all remaining interviews in Phases 1 and 2. We wrote memos on the data and the codes throughout the coding process. We then did another round of affinity diagramming and deductive analysis of the coding library, affinity diagram from the surveys, and memos based on our research questions. Four primary themes emerged. We analyzed remaining data based on these themes, while constantly memoing and discussing patterns of similarity and differences in the data.

To answer **Research Question 3** (*RQ3: How can technology catalyze pivotal experiences for people who are not yet motivated to change*?), we arranged the feedback on the designs in Phase 2 interviews into a coding sheet for our design space framework. For each participant and each parameter in the design space, we marked a checkmark if they clearly liked the feature, an "X" if they clearly disliked it, and "undetermined" if it was ambiguous or ambivalent. In addition, we also added their qualitative responses to support our code, specifically, what specific aspects of a feature did they like or dislike and why. As we sought feedback on the overall narratives in the story boards and did not present the design space parameters to participants directly, not all participants commented on every aspect of the design space. We only coded responses in which participants clearly expressed like or dislike, and added qualitative quotes for those that were ambiguous to the team. Participants also envisioned ideas to improve on the designs, which we added to the coding sheet. We inductively analyzed all responses and codes. (see Appendix C, Table C.1, for summary table of data analysis).

4. Findings

From our analysis, we present integrated findings of data sets from phase 1 and phase 2 to answer RQ1 and RQ2 and feedback on design space from phase 2 interviews to answer RQ3. Of the 117 complete survey responses in Phase 2, 58 participants (50%) reported they believe they had a pivotal moment during their behavior change, 34 (29%) reported they did not, and 25 (21%) reported they were not sure. Of the 35 people who accomplished their change, 23 (66%) reported they had a pivotal moment and 32 of 73 (44%) participants who were currently working toward their change reported a pivotal moment. In addition, 2 of 7 participants who had decided to change but not taken any action toward it and 1 of 4 participants who had not succeeded in making the change, also responded that they had a pivotal moment

4.1. When are pivotal experiences manifested during the change? (RQ1)

Participants (n = 58) reported on pivotal experiences during various stages of making their change. Pivotal moments occurred when some participants were unaware that they needed to or could make a change, when they had started thinking about making change for the first time but had not acted on it, after they had already been taking steps toward making their change, and even after they had relapsed multiple time. For those who had not started acting on the change, their pivotal moment increased their ability or resolve to change. For some participants, a pivotal moment occurred admits self-driven effort of seeking help until they found information or social support that helped them follow through with their change. For example, finding the right resources and information online was pivotal for IA05 and IA08. Both these participants quit smoking after multiple previous attempts followed by periods of either returning to smoking like they used to and not act on quitting or persistently seeking multiple resources and information for support.

In addition, for some participants, their pivotal moment was a *serendipitous or opportune moment* of many factors coming together and increasing the urgency, need, or ability for taking an action. For example, IC12 commented, *"It happens when it has to happen."* In another example, IA11 said he quit drinking immediately after his decision to change. He explained that his dad read out loud a letter addressed to him and his brother at a family dinner on New Year's. This event

aligned with the day he was feeling guilty about his actions from when he was drunk and blacking out the night before:

> *"think it was all timing. If he had talked about it [dad's own challenges with alcoholism] a week earlier, it probably wouldn't have had much effect… And the combination of the night before [and] him re-emphasizing his own struggle with alcohol, and this letter from when dad said he was proud of me, I think all coalesced. It was like … a bundle of emotion."*

4.2. What factors lead to pivotal experiences in making progress toward behavior change? (RQ2)

We aimed to understand what factors constituted a pivotal moment and how those were different from non-pivotal moments. The four themes in this section – prolonged discontent, significant changes that increased fear or hope, increased understanding of one's behavior, and social accountability – emerged from our affinity analysis of participants that reported experiencing a pivotal moment in both phases. The first two were dominant themes described by majority of participants as their pivotal moment. The latter two were described as pivotal by fewer participants. However, all participants mentioned social accountability and/or understanding their behavior as a means to change during or immediately after their pivotal moment.

Participants who said they did not have pivotal moments or were not sure, also described similar factors that helped come to their decision to change. However, they often mentioned a combination of these factors and/or that the change happened over an extended period of time. They used terms such as "gradually," "period," "naturally," and "once I settled" to describe what led to their change. They did not point to any specific moment. For example, SA01 explains, *"I think it was just a gradual change. Like there wasn't one specific moment when I decided I didn't want to any more. I had just slowly stopped eating red meat and didn't miss it anymore afterwards."* Participants who were not working on their change (undecided or not succeeded) and did not have a pivotal moment said they lacked the motivation (e.g., "*It's just my thinking that I need to overcome*" – SC25), did not find support that worked for them, and/or did not have access to necessary resources (e.g., "*Lack of availability of suitable therapy (options limited by affordability, insurances, etc.). Friends not caring.*" – SD01). We also asked all participants who accomplished their change to describe barriers they faced while making the change and how they overcame them. While doing so, they also described other experiences or events without which they might not have been able to follow through with their change, such as finding a supportive advisor in graduate school to help them find time for their behavior and continue education (IA07) or finding mentorship in a friend who ran with her (IC02).

There are variations between what experience each participant perceived as pivotal and what we (researchers) considered was a pivotal moment for the participant. Here, we will describe our findings as perceived by participants and explain the nuances in our perceptions.

4.2.1. Theme 1: Prolonged discontent with self and desire to change

When asked to describe what led to the pivotal moment or their life just before the pivotal moment, most participants described prolonged feelings of *"distress," "hopelessness," "numbness', "helplessness,"* and *"despair."* These feelings stemmed from feeling discontent with themselves such as their psychological state (sadness, depression, unhappiness, stress), physical health (e.g., reduced stamina or strength, or being constantly tired), physical appearance (e.g., weight), or sedentary behavior. Their pivotal moment was not particularly triggered by any external factor. For example, SC58 explains what led to the pivotal moment as,

> *"Despair. Succumbing to depression, and the horror of that. This led me to a kind of personal epiphany. There was an implied ultimatum: Change or suffer/die."* – SC58

Participants said their desires to change were also motivated by feeling a lack of control over their life, especially due to addiction to substances such as cigarette smoking or alcohol. These participants spoke about wanting to regain agency and control. For example, IA08 and SC31 describe their pivotal moments for deciding to quit cigarettes,

> *"also dislike the idea of something having power over me. I want to be in control of my affairs and not a slave of say for example, cigarettes!"* IA08

> *"just suddenly realized that I had become a slave of cigarettes for 16 years and I hated myself for being dependent on it. I hated myself for not being able to control my cigarette addiction."*—SC31

Some participants said that such feelings of discontent and lack of control led to a moment of self-resolve where they started pro-actively seeking out information and/or support. SA19, who started working on losing weight, quitting smoking, drinking, recovering from addition describes his pivotal moment, *"I hated my life and realized that I needed to change."* Others echoed these sentiments:

> *"guess I realized that I had given up and then I felt really bad like - Oh my goodness, I'll always be this way. And then I thought - well, I don't have to… and then I realized that I didn't want to give up and I realized that I'd better do something."* – PI06

> *"got to a point where I just felt awful about myself all the time, and it was nobody's fault but my own. So, I started changing."* – PI05

4.2.2. Theme 2: Significant changes that increase fear of or hope for the future

Many participants spoke about significant events that made them think about their future differently. This difference in perspective was triggered more often by negative events than positive. These changes were driven by necessity after unexpected or uncontrollable health related diagnoses, external social and environmental circumstances, and internal sense of increased responsibility.

Negative events related to **personal health** caused participants to fear having a worse future – or no future – if they continued their current behavior. Pivotal experiences included contemplating the possibility of a reduced life span after receiving a medical diagnosis for themselves or learning that someone closely genetically related had been diagnosed with an illness such as diabetes and cancer. Three participants also described turning a certain age as pivotal milestone. When people's behavior or circumstances did match their expectations for where they should be at this age, they perceived the milestone negatively. For example, some participants thought they needed to become more mature or less reckless, and others felt their body is "not as young as it was before" (this age ranged from turning 35 to turning 50).

Negatively perceived external circumstances stemmed from threat or damage to self-image, loss, or separation from another – such as, losing a job, the loss of someone they care about deeply (such as sibling, parent, or pets), and even the near-death experience of their plane almost crashing. SC13, who started working on quitting drinking and smoking, increasing physical activity, and changing her diet, explains her decision to change after election results she considered unexpected and undesirable,

> *"I've been putting off quitting smoking until the right moment comes. I thought that moment (this time around- I've quit plenty of times) would be after the US presidential election. After the election, I had an epiphany. There was never going to be a good time. And if I can do it now, then I can accomplish anything."*

Some did not realize on their own that their behavior was harming them until it escalated to a critical point and other people called their behavior to their attention. These included unexpected hospitalization and intervention from a medical provider, coworkers mentioning behavior they tried to conceal or were ashamed of showing in public,

neighbors calling police, and break-ups or being rejected by someone they like. For example, IA04 describes her embarrassment and guilt with drinking alcohol *after* hospitalization (her pivotal moment) as,

> *"had been drinking on a daily basis, and then I got physically ill…I was in the hospital… they sent a doctor in to ask me if it was intentional. He said, 'What would your parents do with your remains after you have killed yourself?' I was just dumbfounded. I had no intention of killing myself…the fact that they had to ask me that question was so personal, that I couldn't believe that I had damaged myself to the point where somebody out there thought that I was trying to hurt myself intentionally […] it flipped, and when all that happened, I realized I had to change my behavior to deal with personal issues, I couldn't just throw in the towel and start drinking."*

Participants also experienced positive, pivotal milestones in life, such as starting a family, having a baby, the birth of a nephew, or increased foresight of future, wanting to live longer be in their life, finding a significant other that they deeply care about or who cares about them. In all these milestones, participants felt increased responsibility toward themselves or others that they care about or want to care about, which led to increased resolve toward making the change. For example, SA55 describes,

> *Having a child motivated me more than anything. I now have to take care of myself for him, and want him to begin/live life as healthy as possible.*

Major events also included a change of environment for some people. Positive and desirable changes in their environment included visiting a friend who is an athlete, going to watch the Olympics, or moving in with a supportive aunt after moving away from a family and friends struggling with addiction issues. Negative environments included transitions to more stressful environments such as a workplace that demands a lot of physical strength or has no windows motivated participants to start making the change.

4.2.3. Theme 3: Increased understanding of one's behavior and personal data

Some participants either proactively sought or unexpectedly came across external information that helped them increase their understanding about their behavior and personal data–such as understanding causes, consequences, and struggles with their behavior or diagnoses. Participants described this process as doing "research" for information and resources online and offline. SA06 and PS56 summarize this process as,

> *"Internet research to find the best foods and drinks to increase health, and supplements that would benefit the mind and body."* – SA06

> *"was fed up with the symptoms of chronic fatigue and had seen a lot of doctors that were not able to help me get better. I started doing internet research, and I remember the night I read about the benefits of a raw food diet - I totally overhauled my kitchen cabinets and began a healthy eating journey the next morning."* – PS56

Participants sought both medical knowledge and experiential knowledge. Participants gained this external information through classes, mentors, peers, online communities, medical information websites, or blogs by people going through similar changes. For **medical knowledge**, they cited using websites such as WebMD, the Mayo Clinic website, books, or PDFs of information about quitting smoking. Some spoke about their pivotal moment as a feeling of resonance or clarity after reading certain information after a long period of trying different books and watching YouTube video tutorials to have the right information (IA04 described this experience as, *"I quickly realized I'd finally found the truth"*). To seek **experiential knowledge**, they participated in online communities on Instagram, Reddit, Imgur, or whyquit.com. Even if they just passively followed or viewed information in these communities, they valued that it came from "real" people who have undergone similar changes. Pivotal experiences were described by them as relating to and validating their current struggles, feeling inspired by another's change, and realizing that it is possible to change. SC21 describes his use of technology in his pivotal moment as, *"Yes, [I used technology] to find inspiring stories from people who solved the same issues."* Another participant SA25 describes a similar experience offline,

> *"Pivotal moments occurred when I met others on the same journey that became friends. Surrounding myself with others that were attempting to do and were going through a similar situation helped keep everyone on track."*

Being able to **externalize, visualize, and reflect on their own data** from medical reports and using logging or tracking apps was described as representing "reality" by some participants. Participants perceived this type of reflection to be helpful even if they logged their behavior without making any changes and reflected on it over time. IA03 explains that her coach she met through Instagram, guided her to log her calorie data on the app MyFitnessPal, which helped her be aware and conscious of her food intake:

> *"was just used to eating what I wanted and however much I wanted. Now it was like, "Oh, here's what an actual serving size looks like.' Finding a food scale, I was like, 'Oh, here's what four ounces actually looks like" versus what I was eating. [My mentor] would have us do these comparisons and would be like, "Look a few weeks back to what you were eating and put that into My Fitness Pal so you can visibly see how much you were eating." She showed it from two years prior for herself for a normal day and she was eating like 8000 calories versus 1800 calories. Actually being able to realize, 'oh my gosh, you're eating so much without actually noticing it because you're not aware of it.'"*

4.2.4. Theme 4: Social accountability

From our surveys, 91 participants in Phase 1 (72%) and 62 participants in Phase 2 (53%) said that another individual encouraged them to decide to change. People who encouraged participants to change included spouse or significant other (28%), friend (27%), parent(s) (22%), doctor (20%), sibling (9%), coworkers (9%), and child (5%). Other responses included anonymous people, relative(s), and their mother's best friend. 20 participants mentioned one of top three motivation as being role models for others, primarily their children.

In Phase 2, 33 out of 58 (57%) survey participants who had a pivotal moment responded that no one encouraged them to change. However, during our follow-up interviews with 9 participants who had selected "no one" in their survey response, we learned that discontent with themselves led them to open up or become vulnerable about their desire to change to another individual in their trusted social circle, such as a friend, teacher, parent, or significant other.

As explained in theme 1, majority of participants recounted discontent with themselves as leading to their pivotal moment (theme 1). Some of these participants reached out for social support by using messaging technology in their pivotal moments or right after, while others found support during regular conversations (as they were regularly in contact with this individual). Few others regarded receiving positive negative intervention from another person, such as talking to their mother in the car or a conversation with their father, as their pivotal moment. These individuals were then supportive by either suggesting ideas for activities they knew the participant liked doing or had done in the past because through their close social ties, they knew the participant well. In some cases, they also helped by increasing financial means and accountability to change such as by gifting a gym membership. Some people took the next steps toward changing together such as by offering and/or mandating that they run together (IC02) or attending support groups together (IC12). SC40 describes her pivotal moment as a New Year's resolution she shared with others (not on social media),

Table 6
Technologies that Phase 2participants described using in their pivotal moment.

Function of technology in pivotal moment	Examples of technologies used by participants
Finding information	Websites such as Mayo Clinic, Web MD, University affiliated health sites, Whole30 website, whyquit.com (to learn about quitting smoking)
Connecting with friends	Facebook chat, Snapchat, and texting
Finding a community & sense of belonging, finding encouragement & inspiration from public posts, sharing and relating with experiential knowledge of peers	Instagram, YouTube, and Facebook
Self-tracking apps	*Health:* My S Health app, Sleep Cycle, Sleep Better, Fitness app to track food, Food diary, MyFitnessPal, MyPlate app, Mi Coach (Adidas) to track runs, Nike + run app *Finance:* personal bank app, Discover app
Coaching platforms	Lose It (weight), Headspace (for meditation) Peak, Elevate, Lumosity (for cognition)
Reminders	Setting multiple alarms on phone (to regulate bedtime)
Other	Listening to music such as iTunes (for running), 1 Second Everyday (an app that lets you capture 1 s of video per day)

"When I committed to doing yoga for 31 days in a row and told other people about this goal."

We note that social accountability played a key role in helping individuals follow through with the change after their pivotal moment. Two interview participants (IA01 and IA03) paid a coach or professional, providing both social accountability of someone checking in on them and financial accountability. Few participants said that they eventually had to move away from close relatives or friends or did not find a buddy in their new location. These participants communicated through either text messaging or Snapchat to coordinate running at the same time but separately. IA07 specifically said she did not like to run with others but still coordinated times with her roommate via text, which she mentioned as "*Accountabilibudies*". IA10, mentioned she would text her friend in a different city, then leave for the run, and return at the same time. She explains,

"mean I moved here by myself… sometimes—with a good friend in another city, we'll kind of go on a run together. But we'll basically text beforehand and kinda go our separate ways, and then come back and text or Skype or something like that…if we're trying to do a challenge where we have to do number of minutes planking per day and it's the same date. So, like today is the ninth so you'd do nine minutes of planking during the day. So, we'll Snapchat a picture to each other just as an accountability thing."

4.2.5. Role of technology in pivotal moments

In Phase 2 surveys, we asked respondents whether they used technology in their pivotal moment and, if so, what technologies they used. Forty out of 58 participants who had pivotal moments 39 (67%), described using **technology** in the pivotal moment of their change (12 accomplished, 24 currently working, 2 not started, 1 not succeeded). Table 6 describes some examples of applications that people used in their pivotal moments. Some participants did not mention using a specific website or an application, but mentioned using the "internet," "my phone," or using Google search engine to search for personal stories, articles, online communities, offline events and communities in local areas, and doing "research" to access resources for self-help and relevant to their behavior change. Some participants also mentioned using "books" and "running shoes" as a technology.

Interestingly, among these 40 participants, only 3 said that technology caused or "led to the pivotal moment", which included seeing pictures from a past event or on Facebook. Discontent due to viewing photographs led to pivotal moments only for 2 participants. For all 40 participants, technology acted as a tool and a reinforcement immediately after their pivotal moment and the perceived immediacy reflected that they considered it as use "in that moment." Technology was also used extensively for identifying and executing on the next steps from that moment. We describe this progression of role of technology with a representative example of SC57 who was working on losing weight, change of diet, and physical activity. SC57 describes how his pivotal experience was panic after visiting doctors and technology as an encouragement "in that moment":

Describe that [pivotal] moment: *"I had a panic attack that the doctors were concerned about my heart. Which led to a nuclear stress test, an MRI, ultrasounds to figure out what was going on with my health. I had back aches, swelling in my face and hands, diarrhea and migraines."*
What led to that moment: *"Felt panic, overweight, helpless, sad."*
Technology used in that moment: *"Yes! Lose It! and Instagram/ Facebook for sites to encourage me."*
Next steps from that moment: *"Walking further, changing my diet, slowly eliminating foods from my diet I might be allergic to. Also, following some Instagram sites that are supportive and encouraging."*

4.3. How can technology catalyze pivotal experiences for people who are not yet motivated to change? (RQ3)

To answer our third research question, we developed a design space (Table 7) for opportunities to catalyze pivotal moments for people who are not yet motivated to change and support them in the moment. We derived this design space based on a review of related work (specifically focusing on [1,12,31,35,37]), preliminary findings of factors that catalyzed the decision to change for participants in Phase 1, and relevant existing technologies. The dimensions of the design space are:

1. *Area of change:* To consider what behavior(s) the person may want to or need to change.
2. *Means of introduction to technology:* How might an individual who is not motivated to engage in behavior change be introduced to a technology for behavior change? One might come across such technologies through self-discovery or be introduced to such technology via others such as a family member, coworker, or doctor. As evident in our findings, social factors were important for encouraging participants to change.
3. *Nature of exposure to technology:* Following the introduction to technology, the intent of exposure to features that can catalyze their behavior change can be intentional (when they are aware and seeking ways to change) or unintentional (they may come across it accidentally while browsing for something else). How can adoption be encouraged when introducing such technology: can the purpose of technology be stated explicitly or be introduced such that it implicitly nudges the person in the direction of change by tapping into their personal interests and history?
4. *Framing:* Is the content or feedback framed to accentuate negative, positive, or neutral aspects of behaviors and behavior change? Here, we note that if a technology makes people unhappy, they can

Table 7
Design space characteristics (left) that we intended to impart to our three design sketches to elicit feedback from participants.

	Reflecting Pool	Quit It	Challenger
Area of change	Socializing	Smoking	Physical Activity
Means of introduction to technology	Self-Discovery	Social: Wife	Self-Discovery
Nature of exposure to technology	Unintentional, Implicit	Intentional, Implicit	Intentional, Explicit
Framing	Neutral	Negative	Positive
Comparison with	Past self	Perceived self (current)	Past self, peers
Pivotal moment features	Collage timeline, encouraging reflection	Self-tracking, increased awareness	Challenging friends, social incentive
Supporting features after pivotal moment	Reminders to add pictures of socializing	Tracking, leading to long term non-use of the application	Sending challenges

change their behavior to deal with the discomfort, or they can abandon its use so they don't see the framing that adds to their guilt and discomfort.

5. *Comparison:* Is the technology providing data or information to help catalyze comparisons with oneself (past, future, perceived present self) or with others (peers, family, celebrity, average population)?
6. *Pivotal moment features:* What are the features or functions of the technology that are expected to catalyze pivotal moments? Does it increase awareness of self or external factors through presentation of information (own data, educational information), increase ability, increase engagement by personalizing, or provide social incentives?
7. *Supporting features after pivotal moment:* What features or functions of the technology can support people in taking action toward their change during or after their pivotal moment? Some pivotal moments are unexpected or uncontrollable, and people sometimes use technology as a means to find support during or right after the moment.

Using these seven dimensions, we developed three storyboards depicting ideal experiences with technologies that prompt or support people going through pivotal moments: Reflecting Pool, Quit It, and Challenger (Table 7). The storyboard narratives were collectively prepared by the research team based on principles of persuasive design [37] and Behavior Change Techniques (BCTs) [1], reading survey and interview analysis from Phase 1, and reviewing relevant existing technologies (Table 8). These three storyboard narratives were then presented to interview participants in Phase 2, as explained below (see Appendix A, for complete storyboards presented to participants during interviews).

Below, we summarize findings from analysis of the feedback from interview participants on these three designs. Overall, no participant was sure whether these designs could lead to pivotal moment for people who are not motivated to change. However, participants agreed that these designs could support them during or after the moment and suggested improvements, primarily geared toward positive framing.

In **Reflecting Pool** (Fig. 2), we represented the pivotal feature of a collage of images over past 5 years to indicate reduction in the character's socializing behavior after joining the workforce. Although we intended the framing of Reflecting Pool to be neutral as the app only presented a collage (Table 7), most participants perceived it as being negative. For example, IA06 reacted, "*I don't think I would notice the difference in my body that quickly, and so seeing these photos probably wouldn't trigger happy thoughts.*"

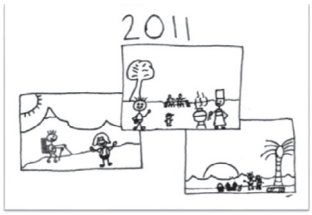
Reflecting Pool was envisioned to pull images from media for personal viewing. The intent was not social comparison but comparison with past-self. Many participants compared Reflecting Pool with similar features on Facebook [38] and one compared it with the Timehop app [48]. As a result, two participants critiqued that social comparison could potentially lead to the phenomenon of social-media depression [7]. IA11 commented, *"There does seem to be some connection with social media use and depression. So, if someone doesn't have a social life, going on social media makes their social life worse, so they feel worse about themselves."* Along similar lines, IA07 explained her view of "Facebook depressiveness" as, *"…where the more you look at Facebook and Instagram the more depressed you are because of the way that people curate their lives on social media. If his issues are with stress and lack of sociality, I think the app has to be something beyond perpetuating that sense of FOMO or that sense of 'Everyone's life is perfect except mine.'"*

IA07 further suggested that systems that present comparisons with a past-self should take into account that people's responsibilities may change with time, and the framing should present positive examples tailored to those contextual changes. She shared her own experience, *"Snapchat has kind of revolutionized how I connect with my friends because we snap each other stupid, mundane stuff and it's like, 'oh yeah, we're also spending eight hours a day in an office, where this is my face when I'm on the computer.' That kind of makes me fell way better than seeing like, 'Why is that friend going hiking? Why I am not hiking right now? Oh, because I have a job.'"* No participant said they will be motivated to add their own pictures by following the reminder(s).

In **Quit It** (Fig. 3), most participants appreciated the pivotal feature of presenting results to make the user aware of how much they are smoking by logging their own behavior. Some related it with their own experiences of realizing they need to change. IC03 said, *"It becomes really eye opening."* IC03 and IA07 compared Quit It to a calorie counting app (MyFitness Pal) that helps a user realize how much they are eating. This feedback also connects to Theme 3, where participants benefit from using tools to develop an understanding of their own data. IA01 reacted to view of the user's smoking history, "*it represents reality, rather than just some annoying dinging app.*" There was no consensus among participants on whether they thought this design would help a user quit smoking, but they unanimously expressed that it could help users realize that they needed to cut back. IA04 related it to her experience of quitting drinking and IA10 expressed that they could use an

Table 8
Summary of Behavior Change Techniques [1] and persuasive design principles [37] in storyboard design scenarios.

Storyboard scenarios	BCT strategies	Persuasive design principles	Example existing technologies
Reflecting pool: App shows collage of photos of past self	Prompt self-monitoring behavior, Teaching to use prompts	Primary task support -Personalization, Dialog support – reminders	Facebook: On this day, Timehop [48], Drinking Mirror [46]
Quit It: App prompts the user and logs choice made by the user	Plan social support or social change, prompt self-monitoring behavior, provide feedback on performance, prompt intention formation	Social support – normative influence, Dialog support – reminders, Primary task support -self-monitoring	Alarm clock or reminders, Twitch crowdsourcing [45]
Challenger: App allows user to send challenges to her friends wherever she may be and tracks score	Provide opportunities for social comparison, plan social support, set graded tasks, provide contingent rewards, prompt intention formation	Social support – comparison, Dialogue support – suggestion, reward	Fitbit's social features, Pokémon GO, Learning to love you more [47]



John notices a sharp decline in the number of social events he's been attending and changes in his physical appearance.

John was socially active in his youth and early twenties. After college, he slowly began to phase out the activities he enjoyed when he was younger as the stress of his job increased. Scrolling through blogs on photography, John stumbles across and interesting application. John Downloads the app on his phone and connects it to a few photo-sharing applications. He's presented with a collage of photos he's been tagged in. John notices a sharp decline in the number social events he's been attending and changes in his physical appearance. John is unhappy with this trend and realizes he wants to make a change in his behavior. The app periodically prompts John to update his timeline with new photos. This encourages to go out and be active and social.

Fig. 2. Storyboard narrative 1: Reflecting Pool.

app like this to cut back on other habits like watching too much Netflix.

Participants were intrigued by Quit It's feature of increasing the frequency of prompts as the user chose to smoke more and did not perceive it negatively. Additionally, IC09 suggested that the app also provide a short summary of the user's smoking history when it notifies the user to smoke so the user might realize more quickly how much she/he is smoking or be motivated to not smoke if they've been successfully cutting back. IA07 suggested that following the realization, Quit It could provide positive reinforcement and meaningful rewards when users refrain from smoking, *"People like having records and having streaks and breaking their records, and that kind of stuff. If you could tie it with actual, 'You just earned a dollar at this brewery', or something like that. Where companies could buy into pieces of the app and give incentive for people to stop smoking, that would be pretty cool!"*

On the design of **Challenger** (Fig. 4), some participants stated that they were not very competitive themselves and might not want to compete with a friend. However, they still saw the appeal of connecting with friends, preferring to instead use the app for collaboration. Few acknowledged that light competition can motivate one to be more active. IA06 related it to her experience of playing a game with an app she and her colleagues created at work,

> *"That [Kitchen Bowl app] was a place where people could upload recipes, and it was like a community of people uploading their own personal recipes. Then, there was also Fork It [the gaming part of the app], where you could compete with your friends to see who cooked the most dishes in a week. You went up like … The idea was that you were supposed to get prizes, but we didn't quite make it there. Just working there, and needing to play the game in order to test out the products, actually created a habit in me to cook all different meals… I'm not too interested, and I know some people are, I think having this light competition with your friends, like people you actually know, is nice."*

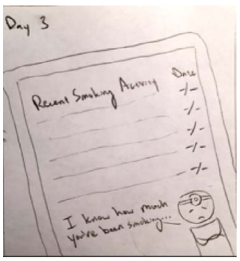
Participants particularly liked the supportive feature of getting challenges on the app. They saw the construction and completion of "challenges" as not necessarily competitive but rather a creative endeavor. IC09 suggested that Challenger could be improved by personalizing challenges of different types, "*if you wanted to be more* [athletic, you get] *athletic-based challenges—or social-based challenges, or you find different categories, where you can set your preference*." IA07 suggests a combination of the Reflecting Pool and Challenger designs to have photo-based challenges: "*Make a field guide to your yard. That's so fun. Three photographs of things in your backyard.*" She recollected a website called, "Learning to Love You More [47]," where *"every week they put up a new challenge for you to do with someone you loved. Be it a friend or significant other or whatever. It was like, "Take pictures of the clouds in an artistic way.'…I think the quality of the challenge would be the thing here because I did a bunch of those back in the day with someone and it was just lovely, it was just magical."*

5. Discussion

Our findings highlight that many people do experience pivotal moments during behavior change. In this study, we sought to learn, (RQ1) when are pivotal moments manifested in the process of behavior change toward personal wellbeing, (RQ2) what factors lead to pivotal experiences in making progress toward behavior change, and (RQ3) how can technology catalyze pivotal moments for people who are not motivated to change yet? Pivotal moments may occur in any stage during the change and catalyze transitions through stages. For example, such moments can help one to start acting on the change "immediately" after decision to change and quit addictive behaviors indefinitely. Key factors that constitute a pivotal moment include (1) prolonged period of discontent with self and desire to change, (2) social accountability, (3) increased understanding of one's personal data and behavior, and (3) significant positive or negative events that increase hope or fear of future, respectively. Technology was a factor that led to a pivotal moment only for three participants. Most participants reported that they used technology in their pivotal moment (e.g., to access positive social support or informational support during the pivotal moment), and to take steps after the moment.

5.1. Conceptual understanding of pivotal experiences in behavior change

In this section, we revisit relevant theories of behavior change in the light of our empirical findings. The Transtheoretical model [40] and the Precaution Adoption Process model [49] describe progression of



This time, instead of offering Ron a smoke break, the app displays Ron's recent smoking activity.

Ron is in his mid-40s, but he has been a smoker since his early 20's. His wife, doctor sees Ron's worsening conditions and recommends him a new application for his phone. The app serves two functions: (1) Notifications: The app will notify the user and present the option to smoke. If the user gives in, the app with notify the user more frequently. If the user resists, the app will notify the user less frequently. (2) Logging: The app will log each choice the user makes. If the user is smoking very frequently, they will be shown a log of their smoking history. For the first two days, Ron goes about his day as usual and smokes when the app prompts him to. On the third day, Ron realizes that the app is notifying him to smoke before he was even done with his last smoke break. This time instead of offering Ron a smoke break, the app displays Ron's recent smoking activity. Ron did not realize how much he was smoking, and is determined to resist the urge to smoke.

Fig. 3. Storyboard narrative 2: Quit It.

Lina installs and tries out an app that allows her to send challenges to her friends wherever she may be.

Lina is a 21-year old senior who commutes to college. Due to her heavy workload, she is unable to exercise as much as she would like to and often finds herself out of breath simply walking from class to class. Her busy schedule also makes it hard to find time to spend with her friends. Certain that there is a way to stay in touch with her friends, Lina checks out the app store. Lina install and tries out an app that allows her to send challenges to her friends wherever she may be. Lina completes the first challenge, find the nearest mailbox and sends it to her friend Amy. After the app has recorded both players' scores, Amy turns out to be the winner. Lina thinks back to high school when she and Amy were neck and neck on the track.

Fig. 4. Storyboard narrative 3: Challenger.

individuals through "stages" of behavior change. Our findings support that not all participants followed similar trajectories of change and revealed greater nuances such as periods of discontent with self, risking vulnerability by reaching out to other individuals in-person or via technology, finding information or resources to change, and developing a better understanding of their behavior. For many participants, their change happened in this order, though this ordering is not universal. Different moments were perceived as pivotal by different participants, and some participants perceived more than one of these experiences to occur simultaneously "in that [pivotal] moment," leading them to immediately start acting on the change and eventually accomplish it.

Our findings demonstrate how psychological conflict between one's current physical and mental state and perceived or desired state – as explained in Cognitive Dissonance theory [20] – was pivotal for many participants. Discontent or emotional chaos was also explained as an antecedent to epiphanies by Chilton [10]. In addition, external factors which were perceived as undesirable and/or beyond the control of participants also triggered discontent—such as embarrassment due to outing of one's behavior and loss or separation from another. It is possible that inducing a period of discontent and vulnerability might catalyze an epiphany and increase self-resolve. Some pivotal experiences that preceded discontent due to a life event would not be possible to induce, and inducing others presents ethical challenges. Manipulating perceptions of self-image and increasing fear, guilt, shame, and isolation to push someone to change their behavior, especially addiction and physical appearance, is a popular strategy in health promotion campaigns, media, and advertising [4,30,36,51]. The HCI and health technology communities should continue a vigorous debate about the ethics of inducing such discomfort.

Participants also considered regaining control in their life as pivotal in increasing their resolve to change, which is consistent with the desire for autonomy and competence as predicted by the Self-determination theory [17]. Social factors, both offline and online, played a key role in increasing a person's resolve to act toward impression management [23], increasing accountability, providing access to medical and experiential knowledge, and increasing their ability to change (such as financial support for finishing school or going to gym). All interview participants in phase 2 explained stances where they presented their backstage [23] or vulnerable state to close social ties and/or mentors. This enabled the social ties to reach out for support by providing recommendations and means to change and increasing social accountability. To that end, out of the Behavior Change Techniques (BCTs) [1] used in our design scenarios, planning for social support, prompting intention formation, and self-monitoring behavior were perceived as more helpful. Participants had mixed reactions to social comparison and described providing general encouragement and contingent rewards as necessary support after pivotal experiences even though they were not included in our storyboards.

5.2. Designing for people who are not motivated to make a change

We identify five key recommendations for our design space from participant feedback on the storyboards presented in Phase 2 interviews. These recommendations address the framing, pivotal features, and/or supportive features: (1) increase awareness of behavior by facilitating better understanding of one's own data, (2) make people aware of their behavior while valuing changing contexts and responsibility, (3) encourage collaborative and creative ways of engaging with the behavior, (4) personalize strategies for behavior change to one's interest, and (5) provide positive reinforcement and meaningful rewards for people who are not motivated to change certain behaviors.

Recommendations 1, 3, 4, and 5 are consistent with prior research in persuasive design for motivating behavior change [12,13,37]. These four recommendations align with design principles in Oinas-Kukkonen's Persuasive Systems Design Model framework [37]. The first recommendation suggests increased *self-monitoring*, the third, *cooperation*, the fourth *personalization*, and the fifth *praise* and *rewards*.

The recommendation to **value changing contexts and responsibility**, while not found in prior research, suggests complex nuances in the principle of self-monitoring and how to present this information to people. Technologies such as Pensieve [15,39], Facebook's On This Day feature [38], and Timehop [48] encourage reflection on past memories. While reminiscing on old photographs can encourage a person to change (such as when they notice weight gain and start acting to reverse this gain), framing of memories in such technologies should take into account what can or cannot be practical for a person given their current context and constraints (e.g., lack of time due to current job). An interesting area of research here is: how can technology can make the person self-aware of their changing context and responsibilities? This might be possible by automatically acquiring additional contextual knowledge through information in a users' profile such as their current work or major life events (if shared and accessible). Recent features in technologies can also help recognize of levels of distress (self-reported reactions or automated detection by logging engagement and abandonment pathways), and tailor feedback.

If the technology can be introduced through social ties such as friend or family, these social ties can also help personalize pivotal features: such as curate collages or symbolic representations of relevant past memories or future aspirations, or create and incentivize challenges based on their knowledge of a person's interest and context. These curations can be then presented to people who are not motivated to change in various ways discussed in our design space. Adoption and engagement with technology have also been known to drop off as novelty wears off [11]. Designing to **generate creative and personalized challenges** to engage with the behavior, provides opportunities for increasing engagement, curiosity, supports novelty in everyday life, and provides increased accountability if they foster collaboration.

Consolvo et al. [12] argue for positive to neutral **framing**. Our

findings suggest that negative events and discontent were more frequently cited as factors that led to a pivotal moment. However, technology was used primarily for positive support during or after the moment. No interview participant approved of using negative framing in our design scenarios to add to distress of someone not motivated to change. Participants perceived the role of technology as what Chilton describes as "messenger of hope" during or after the pivotal moment and not that of causing emotional discomfort that leads to the moment [10]. Participants highlighted how without appropriate support, technology may make someone feel worse and they may even abandon its use without any benefits to their behavior. We also know from personal informatics research that when people see uncomfortable data, they often abandon tracking [18,19] or may choose not to log data if it will reveal inconvenient truths [14].

Finally, recounting their life before changing, some participants described the reason they were unable to change or act on the change was not just due to their psychological state, but also because they did not have access to means for changing, such as lack of insurance for health care, inability to purchase an app or device, stigma, and even not receiving the social support they desire. This was also true for the few participants in our sample who said they did not succeed in making the change. Designers of behavior change technologies cannot simply attempt to manipulate perceptions of self and minimize psychological barriers [26] without recognizing and addressing contextual and structural barriers in making that change. It is important to consider deign space parameter 7—"supporting features after pivotal moments"—to ensure people have access to support and means to change, especially, when the technology may be using negative framing as a pivotal feature.

5.3. Ethical considerations

Ideally, we expect that technology designed to catalyze an epiphany would enable an individual in coming to a decision or make progress toward their change with increased resolve, clarity, and ability [10]. Many participants emphasized that education and access to data helped increase their knowledge about their behavior, what to expect as barriers, and how to overcome them. However, using technology to catalyze factors leading to pivotal moments can be viewed as a form of manipulating a person's agency, self-perceptions, and vulnerability, and can be exploited for commercialization to encourage individuals to buy products for self-improvement [8]. While our stance as researchers is to understand how people can make changes for the better, we also position our work and future work to question who decides what is "good" for a person's wellbeing?

Tengland [43] contrasts the dynamics of manipulative strategies used for behavior change with more empowering measures. He argues for autonomy, providing information about available options, and providing opportunities for sharing expertise with an individual's contextual knowledge. Davis proposes using Value Sensitive Design measures (VSD) and/or Participatory Design methods for assuring inclusion of views from representative stakeholders involved in design of behavior change technology [16]. Participatory Design, however, will be difficult if people who are not motivated to engage in behavior change are not willing to participate. Value Sensitive Design (VSD) [22] may be one practical approach for exploring and constraining the design space based on ethics. VSD encourages researchers to conceptually investigate values and value conflicts among stakeholders and explore ways of accounting for these tensions through empirical and technical investigations. Being reflexive of one's own stance as a researcher or designer is also practice in VSD [22]. Our study attempted to highlight perspectives of peers who have decided to change. Other key direct stakeholders include the individual and their social ties, designers, behavior change researchers. Indirect stakeholders include public health policy makers and health care providers. Value conflicts that primarily need to be analyzed are interests of social good versus manipulating agency and vulnerability. As this VSD approach can be an intensive process, designers and researchers may also look to existing ethics guidelines or develop new ones regarding prompting pivotal moments [28].

6. Limitations and future work

Our findings must be understood in the context that our representative sample is skewed toward people who use online social media platforms. Most of our participants are female, both in Phase 1 and Phase 2. Our methods were primarily designed to encourage reflection from people who have decided to change their behavior and elicit perceptions of participants about those events. Given that some participants made the change over 7 years ago, we acknowledge the possibility of recollection biases. However, if the moment was perceived as pivotal to the participant, they are more likely remember it. Our data reflects stories of success. We encourage researchers to study pivotal experiences that made a person give up on making the change and understand what aspects of design may support those contexts.

As we sought feedback from participants on the storyboards without a concrete structure, our findings about the design space is limited to what the participants found relevant or exciting. This method was successful in getting open ended reactions on the latter four components of the design space and in understanding what participants considered important. However, participants did not comment on the means of introduction or nature exposure to the technology. We recommend that future work should evaluate the design space parameters more explicitly, such as using structured questionnaire for participants to rate and/or comment on each parameter of the design space for each design. Our work leads to opportunities for future work to further iterate on the proposed design space, and to develop and systematically evaluate designs and technologies based on the design space by incorporating more BCTs [1,33] and persuasive design strategies for catalyzing and/or supporting pivotal experiences in behavior change. We urge the persuasive design community to continue discussions on ethical considerations of these types of interventions.

7. Conclusion

In this study, we used interviews and surveys to learn about the lived experiences of people who have decided to make a behavior change, with a focus on the pivotal experiences that motivate behavior change. These pivotal moments occur in behavior change process at various stages and major factors that catalyze pivotal moments include discontent with self, significant external events, better understanding of information on behavior and health data, and social accountability. Participants described planning for social support, intention formation, self-monitoring behavior as important elements of pivotal moments, while receiving general encouragement and contingent rewards were perceived to be important following pivotal experiences. They had mixed reactions to social comparisons. Technologies have the potential to support these techniques and other elements of pivotal experiences, and we describe a design space for catalyzing and supporting pivotal experiences for individuals who are not motivated to change their behavior. We encourage the persuasive design community to continue to explore possibilities in this design space. As our community does so, we must also continue discussions on ethical implications of the use of technology to catalyze and support pivotal moments.

Conflict of interest

Dr. Julie A, Kientz's spouse is a co-founder of Senosis Health, a startup company in the area of health technologies for diagnosis, mornitoring, and treatment, which was recently acquired by Google. All other authors declare that there is no conflict of interest.

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Appendices. Supplementary material

Supplementary data associated with this article (Appendices A, B, and C) can be found, in the online version, at http://dx.doi.org/10.1016/j.jbi.2018.01.002.

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