

Reflective Informatics Through Family Storytelling: Self-discovering Physical Activity Predictors

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ABSTRACT

HCI research has increasingly examined how sensing technologies can help people capture and visualize data about their health-related behaviors. Yet, few systems help people reflect more fundamentally on the factors that influence behaviors such as physical activity (PA). To address this research gap, we take a novel approach, examining how such reflections can be stimulated through a medium that generations of families have used for reflection and teaching: storytelling. Through observations and interviews, we studied how 13 families interacted with a low-fidelity prototype, and their attitudes towards this tool. Our prototype used storytelling and interactive prompts to scaffold reflection on factors that impact children's PA. We contribute to HCI research by characterizing how families interacted with a story-driven reflection tool, and how such a tool can encourage critical processes for behavior change. Informed by the Transtheoretical Model, we present design implications for reflective informatics systems.

Author Keywords

Personal health informatics; Reflective informatics; Technology-mediated Reflection; Sensemaking; Physical activity; Storytelling; Children; Families

ACM Classification Keywords

H.5.3 [Group and Organization Interfaces]: Computer-supported cooperative work

INTRODUCTION

Obesity is a serious epidemic that affects 17% of children and 35% adults in the United States (U.S.) [43], and it severely impacts ethnic and racial minority groups [43] and low-socioeconomic status households [54]. Childhood obesity can pose serious health risks such as diabetes [32] and cardiovascular disease [18]. Interventions for childhood obesity are most effective when they focus on the family environment, a setting in which healthy behaviors (*e.g.*, physical activity) can be encouraged at an early age [23].

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The proliferation of health and behavioral sensors in mobile and wearable technologies has created new opportunities for health promotion. Much of the Human-Computer Interaction (HCI) research in this area of *personal health informatics* (PHI) has focused on physical activity (PA), a behavior that is critical for the prevention and reduction of obesity. By leveraging sensor-collected PA data (*e.g.*, step counts over time), HCI researchers have developed systems that support data visualization, data-driven game play [35,66], and data-grounded social support [41,56].

Few researchers have explored how PHI tools can be designed to support behavior change in the context of the family unit (projects by Saksono *et al.* and Stanley *et al.*, [51,56] are notable exceptions). Yet, health researchers have consistently found that the family environment play a critical role in shaping children's PA. Parental support, for example, is "consistently, positively, and significantly associated with child activity" [60], with involvement, encouragement, and facilitation cited as the most important forms of support [24]. As such, research is needed to explore how technology can *not only help families visualize their behavioral patterns, but also understand and assess the complex and intertwined factors that impact one's ability, desire, and decisions to change behavior*—and highlight opportunities for addressing those factors. Such work is needed to support sustainable shifts in behaviors such as PA.

To address this research gap, we conducted a formative study guided by the following overarching research question: *how can technology encourage families' awareness of individual and social factors that influence their PA?* Informed by work in reflective informatics [3], we conducted a qualitative study with 13 families (13 adults and 17 children). Given our focus on parents and young children, we explored how technology-mediated reflection can be supported through a generations-old family ritual: storytelling. While HCI research has explored various approaches to health reflection, prior work has rarely examined how storytelling might be an effective medium for supporting meaningful reflection and insights in the family setting. As an important first step in exploring this design space, we took a user-centered design approach, constructing a paper prototype that simulated digitally-supported reflection. The prototype consisted of a PA-themed paper storybook with reflective prompts inserted throughout the pages. We then recruited parents with their young children to interact with and read the augmented storybook. These interactions served as the

starting point for semi-structured interviews to probe parent and child experiences with this novel approach to reflection, and their broader perspectives on the role of stories as a venue for health data reflection.

Our findings illuminate how prototype-initiated reflective prompts encouraged conversations related to *processes of change* documented in the Transtheoretical Model of behavior change (*i.e.*, activities and experiences that facilitate behavioral shifts) [47]. First, families engaged in *consciousness raising* and *environmental reevaluation* of factors correlated with children's PA. Participants' reflections also incorporated discussions of family identity, highlighting prime opportunities for *self-reevaluation*—also a *process of change*. We conclude this paper by presenting design implications for reflective informatics [3] in the domains of PA and health more broadly. We discuss how reflective informatics systems can be tailored to individuals' *stages of change* (*i.e.*, readiness to engage in behavioral shifts), supporting stage-relevant reflective storytelling that helps shape PA behavior. Our findings and design implications will inform future HCI research on personal health informatics and reflective informatics.

RELATED WORK

HCI Research on Personal Health Informatics

A large body of HCI research has focused on the use of health sensors for physical activity promotion, often incorporating a combination of three distinct but not mutually exclusive design focus areas: visualization, game play, and social support. Data visualization systems are self-monitoring technologies that collect data about PA behaviors and help users make sense of their data through abstractions such as charts, graphs, and plain language data summaries. Consumer products in this field—such as those from Fitbit, Jawbone, and Garmin—represent an enormous market. The sales of sports wristbands and watches has been forecasted to reach 58 million units in sales during 2016, a 15% growth from 2015 [40]. Within HCI, researchers have increasingly explored the efficacy of novel PA visualizations beyond charts and graphs. Some of these visualizations have taken the form of a fish tank [34], a flower garden [11], and a spaceship dashboard [51]. Other tools show abstract relationships between data, such as in *Health Mashups*, a health app that shows the correlation between health sensor data with other wellbeing data [5].

Data-driven game play systems integrate users' movements with game design elements (*e.g.*, leaderboards, virtual rewards) [13]. Such systems often complement visualization features, as found in consumer health trackers and research projects like *American Horse Power Challenge* (AHPC) and *StepStream* [41,66]. Other systems use movement to control game play, as found in *IFitQuest* and *Play, Mate!* [6,35].

Data-grounded social support systems combine social influence with PA data, such as in Fitbit's leaderboard, StepStream [41], and AHPC [66]. While many social support systems have focused on children or adults

exclusively, a small amount of research has explored the design of social support tools for parents and children [51,56]. Overall, prior research has suggested that health conversations in digital spaces can increase feelings of social support [41] and family interactions can motivate engagement with health technologies [51]. These findings underscore the value of designing social user experiences within personal health informatics tools.

Prior work on visualization systems has shown how self-monitoring through activity tracking and presentation can increase PA intensity awareness. However, many have questioned how these tools can support sustainable behavior change [34,35,58,66]. Health behavior change is indeed a complex process that is affected by a multitude of factors. Klasnja *et al.*, argued that HCI research should evaluate how technology can facilitate change in specific theoretical constructs that affect health behaviors, before addressing long-term health behavior change itself [29]. With this approach, novel technologies can be tested before a controlled long-term study with a large sample is conducted. While the short-term efficacy of self-monitoring has been reported by a vast body of research, such tools have high attrition rates [29]. Individuals may slowly relapse into the pre-intervention behavior when self-monitoring is discontinued. Critically, individuals' ability to maintain the desired behavior after they discontinue self-monitoring is often due to other support structures that they put in place when they were self-monitoring [29].

This research suggests that work in personal health informatics should investigate how health sensing can help people sustain healthy behaviors *beyond a period of self-monitoring*. As such, we explore the design opportunity of helping families construct structures that support long-term behavior change (even if self-monitoring ends), by discovering and internalizing more “upstream” determinants of health—factors that can impact one's likelihood of engaging in healthy behaviors such as PA.

Understanding Factors that Affect Physical Activity

A systematic review by Dishman *et al.* shows that PA behavior is correlated with personal factors (*e.g.*, self-efficacy, enjoyment) and environmental factors (*e.g.*, access to facilities, time, social support) [14]. Sallis *et al.*, describe a similar set of factors that impact PA in children: personal (*e.g.*, PA intention, previous PA) and environmental (*e.g.*, access to facilities, time outside) [52]. Gustafson *et al.*, show that parental support predicts a child's PA level with encouragement, involvement, and facilitation cited as the most important forms of support [24]. Additionally, Trost *et al.* suggest that parental support has a consistent and positive correlation with children's PA [60].

To help individuals gain health insights beyond their sensor data, Bentley *et al.* used self-report wellbeing measures (*e.g.*, mood) [5]. Then, these self-report measures were correlated with health sensor data (*e.g.*, step-counts). Observing this

relationship helped the participants to consider the actions to be healthier.

However, Elsdén *et al.* suggests that there is a mismatch between the information recorded by health sensors and the kind of information that is meaningful to individuals [16]. For example, a run in the park will be recorded as step count data by health sensors. Yet, two individuals' stories about such experiences can vastly differ in what they describe and the details they emphasize. While sensor data may not provide the details that matter most, Elsdén *et al.*, suggest that individuals engage in data *appropriation*: making sense of the objectively measured data with the subjectively remembered past to reach a more complete reconstruction of their lived experiences [16]. This emphasizes the need for tools that help individuals explore and understand their data "beyond just sensor reading" [5], which resonates with Li's position that current personal informatics tools are not sufficiently designed for users' self-reflection needs [33].

Indeed, a natural progression for personal health informatics tools is to use self-reported measures to complement sensor data, in which these metrics can be compared and correlated [5]. However, this approach presents a challenge, as these data on their own are not sufficiently meaningful. A potential research direction is to help individuals reminisce about their subjectively remembered past, through a health and wellness framing. The elicitation of personal stories may provide meaningful data to complement objective measurements and support reflective thinking for health behavior change.

Reflective Informatics Through Storytelling

The distinction between objective data and subjectively remembered past events has been delineated by work in health education and storytelling [25]. Haigh *et al.*, defined *narratives* as factual recollections of the past, whereas *stories* are "reflective, creative, and value laden" [25]. Stories embody the tellers' personal mythologies as well as lessons from their experiences, which helps tellers negotiate "their lives in the world" [31]. *Storytelling*, the telling of personal stories, is a product of reflection that offers the communication of relevant, meaningful, and culturally appropriate health messages [25].

Research in HCI has explored how digital tools can support the communication of stories among children and within families. These tools encompass systems to support collaborative storytelling [4,9,27], enhance storytelling experiences (*e.g.*, using robots, social agents, video feeds) [15,17,48], and facilitate literacy development [10,53].

Another area of work in HCI has explored how digital tools can support reflections that facilitate health and wellbeing. The *MAHI* system demonstrated how the capture of health-related data engaged diabetes patients in the sense-making of their past experiences and helped them to develop the capacity to manage their disease [37]. An evaluation of *Echo*, a tool that allows users to record everyday experiences and reflect on them later, demonstrated how the reflective

process helped users to draw positive lessons, catalyzing behavior change [28]. In *EatWell*, individuals reflected upon and retold health-related positive experiences to individuals with a shared socio-cultural context [21]. Sharing these stories with fellow community members helped reverberate the empowering feelings of "joy, excitement, and pride" within communities, and encouraged residents to address health disparities in their neighborhoods.

Baumer described this emerging area of research in *reflective informatics* as the study of how technology can help people examine personal data, and thus facilitate knowledge or attitude transformation [3]. In the context of personal informatics, *reflection* is the stage where the data has been *integrated* into a meaningful format, and before an individual has performed the *action* for behavior change [33]. Baumer described three dimensions of reflective informatics: *breakdown*, *inquiry*, and *transformation*. *Breakdown* is a surprising realization or a conflicting discovery that does not fit the individual's understanding of her world. *Inquiry* is the re-examination of this previously learned knowledge. *Transformation* is the process of re-conceptualization to reach a more complete understanding of the world. As reflection is a complex process, Baumer suggests that reflective informatics research should evaluate the ways in which people engage in reflection [3].

Therefore, a promising design direction for technology-based health promotion systems is to use storytelling as a venue for reflection. At the personal level, reflecting on current health behaviors can affect one's ability to achieve health goals [49] and improve personal wellbeing [64]. At the social level, storytelling can relay life lessons to younger generations and facilitate family bonding [9,62].

In conclusion, while prior work has shown how self-monitoring can have positive effects on PA, Klansja *et al.*, underscores the need for individuals to develop the structures needed to maintain long term behavior change [29]. As PA is affected by a multitude of factors (*e.g.*, self-efficacy, enjoyment, parental support) [14,24,52,60], an obvious strategy for personal health informatics is to acquire data about these factors using self-report surveys, such as mood scales [5]. However, such data on its own can be less meaningful, as the categorizations available to users may not fully convey the diverse dimensions of their experience [16]. This underscores the significance of stories—a subjective, reflective, and value laden recollection of lived experiences [25]. Furthermore, we suggest that reflection on objective data and personal stories can help families to construct a complete understanding of family's health. We engaged in an initial step in this direction, examining design opportunities for health-promoting technologies that scaffold family storytelling and reflection.

METHOD

We are engaged in a larger research project exploring how personal health informatics tools can be designed for PA promotion in families. The focus of this work is determining

socially appropriate and engaging ways of stimulating health reflection amongst children and their *caregivers* (in our study, we use this term to refer to parents and grandparents caring for children). To explore this design space, we conducted a formative study to answer the following question: *how can technology encourage families' awareness of personal and social factors that influence PA?*

We created a low-fidelity paper prototype to simulate technology-mediated reflection. The affordances of low-fidelity prototypes can help participants think creatively about future design opportunities, without the constraints that a digital prototype can impose (e.g., fixation on low-level visual design elements such as fonts and colors [50]). Using a storybook as the context for reflection, the prototype helped us to investigate how families engage with reflective prompts that encourage joint reflection. We designed the prompts to encourage reflections on factors that correlate with PA, namely *self-efficacy* (confidence in one's ability to engage in a behavior), *enjoyment*, and *parental support* [14,24]. Through our evaluation of family interactions with the storybook and prompts, we identified novel design implications for how reflective technologies can help PA promotion in a family context.

Paper Prototype Design

Our prototype consisted of a paper storybook with reflective prompts. The aim of this prototype was to simulate joint parent-child interaction with a digital storybook and reflective prompts. The *Peppa Goes Swimming* storybook [1] was selected for this study because of the PA-themed stories. In this book, the title character, Peppa Pig, goes to the swimming pool with her family. Her brother, George, was initially scared to jump to the pool, but Daddy Pig gave him parental support in the form of encouragement and involvement. George then became confident to jump into the water and increased his self-efficacy. In the end, the Pig family had a fun day swimming at the pool.

We targeted two subplots in this book as the springboards for reflection: (1) when George Pig was scared to jump into the water and (2) when the family was having fun at the pool. The first subplot was used to initiate *self-efficacy* reflections and the second subplot was used to initiate reflections on *PA enjoyment and parental involvement*.

To simulate digital prompts, we first asked the children to select two animal stickers that they like. These animal stickers acted as cues for reflections that we put throughout the book. When the child found the sticker on the page about *self-efficacy*, the child or caregiver picked one of the five red envelopes that contained a self-efficacy question for both the caregiver and the child to answer. We had five envelopes to simulate gamification, by initiating the notions of limited options and curiosity. The question was worded as follow:

“Can you remember a time when you felt scared to jump into a pool?”

Similarly, when the child found the animal sticker on the page about *enjoyment and parental involvement*, the child or the caregiver picked one of the yellow envelopes that contained enjoyment and parental involvement question:

“What do you like most when you are physically active with your family?”

We designed the prompts to be non-prescriptive and open-ended. They do not didactically inform participants about PA principles, rather the prompts encourage active, constructivist learning as families think about and discuss factors that affect their PA.

These interactions were designed to closely mimic the delivery of health related prompts in a parent-child interaction using a digital system. First, the prompts were designed to encourage *perspective-taking* by inviting the child's active participation to share her/his thoughts, as opposed to participating only as a passive listener. Perspective taking occurs when participants take turns to speak and share their views. Kellas *et al.*, suggests that this is one of the key characteristics of collaborative family-unit sense-making [30]. Prior work [63] has shown that parents have higher control of turn-taking during parent-child conversations. Therefore, we designed an interaction that ensures children have an opportunity to speak.

Second, we allowed the children to *self-select their reflection cues*. We asked them to pick animal stickers as cues for reflection, as opposed to having pre-selected animals or colored shapes. Prior work suggests that one shape or color cue is not inherently superior to another, because each individual interprets these shapes and color differently [67]. Therefore, as the system is targeted at children in the early stages of literacy development, allowing the children to pre-select the notification shape may have better efficacy as opposed to generic cues.

Finally, we put the *interruption* at the end of the story's subplots. Prior work suggests that delivering notifications during task transitions helps the message to be better received [26].

Study Design

We recruited families with young children (3-9 years old) through urban community organizations in the Northeastern U.S. Upon consent, we asked participants to fill out validated surveys on PA intention [12], PA stage of change [38], and demographic data. Then, the research staff asked the caregiver and the child to use our paper prototype: the paper storybook with reflective prompts. We told participants that the research staff will leave the room but will be able to observe their interactions from a live video feed. At the end of the story-reading sessions, we conducted semi-structured interviews to ask the caregivers and their children about their experience. Informed by our live observations through the video feed, we asked caregivers about their experience with the prompts, their experience listening to their child's



Figure 1 Parent-child storytelling sessions in our study

responses, and how these prompts affected them. The median duration of the storytelling sessions was 8:07 minutes ($IQR=4:23$). The median duration for the interviews was 40:09 minutes ($IQR=12:27$). Families received a \$15 gift card for participating in the storytelling session and the interview. Our study design was approved by our University's Institutional Review Board.

We conducted an inductive, thematic analysis [59] of the interview data inspired by Grounded Theory [57]. The first author used open coding to inductively label emergent phenomena in the interview transcripts, meeting regularly with the second author to discuss and refine emergent themes. Open codes were clustered using axial coding techniques to determine higher-level themes.

Participant Overview

Thirty people from 13 families participated in this study (12 parents, 1 grandparent, and 17 children). Almost all of the caregivers were female ($n=12$) and half of the children are girls ($n=8$). The median age of the caregivers was 34 ($IQR=8$). The majority of the children were preschool aged (3-5 years, $n=11$) and the rest were in middle childhood (6-9 years, $n=6$) [68]. About half of the families live in low-income neighborhoods ($n=6$) and about half self-reported annual household income less than the city's average ($n=6$). Six caregivers identify as African-American and four identify themselves as Latino.

Our physical activity (PA) measures show that the majority of the adults self-reported to be in the maintenance stage (had been active 5 times a week for at least 6 months, $n=9$) while the rest were in the contemplative stage (thinking about engaging in PA in the next 6 months, $n=4$). The skew towards the maintenance stage may be due to the fact that almost all participants were recruited through health-focused community organizations ($n=10$). While this data suggests that most caregivers were very physically active, these numbers conflict with our PA intention data: in the next week, most adults only intended to be active once a week or less ($n=8$). This mismatch may be due to the unreliability of stage of change measures [39]. We will discuss the implication of this mismatch in the Discussion section.

RESULTS

Our findings characterize the opportunities for and challenges within story-driven, wellness-centered family reflections. We first overview participants' interactions with the reflective prompts, describing caregivers' scaffolding

strategies and the challenges that children face when reflecting on health related themes. Then, we will describe how the prompts facilitated self-discovery of *caregiver behaviors* and *child-related factors* that impact children's PA behaviors. Finally, we will discuss how family reflections can be a space to nurture family identity. Throughout the paper we use the **-proto** suffix to indicate quotations from the storytelling prototype sessions and **-int** to indicate quotations from the interviews.

Scaffolding Children's Reflections

The majority of the children ($n=8$ families) responded to the prompts with *descriptive answers*—any responses beyond *yes* or *no*. Some children gave detailed answers such as the boy in family #3 when responding to the *enjoyment and parental support* prompt with details about people, objects, and events:

C3-*proto* (4 y.o.): At the beach I like to play with my [brother]. With our equipment, a dump truck will come in and build and get water for you. But sometimes it falls out and sometimes I get sand, and then, and then the ocean, um, fills in the moat.

While this quote shows how the prompts can engage children and families in reflection, more than half of the younger children (3-5 years old, $n=7$) needed time to think about their response, sometimes requiring caregivers' facilitation. For example, the child in family #2 seemed to struggle with the *self-efficacy* prompt. He ended up responding with a non-relevant answer:

P2-*proto*: Can you think a time when you felt scared when being active?

C2-*proto* (4 y.o.): [Paused, gazed away from mother, walks back and forth] One time, I was scared of... [long pause]. Um... [long pause]. One time I was scared about... something I didn't like... like... scary movie.

Several caregivers helped children reflect by *scaffolding the reflection* process ($n=5$). Scaffolding refers to the steps taken by caregivers to lessen the complexity of difficult tasks being carried out by the child [7,55]. We will describe the three forms of scaffolding that emerged during our study: *follow-up dialogue*, *examples*, and *question tailoring*.

Scaffolding using Follow-up Dialogue

When their child seemed to have trouble responding to the prompts, some caregivers ($n=5$) started a dialogue that followed up on the child's initial response. For example, mother #8 asked follow-up questions that helped her daughter describe a detailed reflection about being scared of jumping into a swimming pool:

P8-*proto*: Remember when auntie took you to the, to the pool?

C8-*proto* (4 y.o.): Uh-huh.

P8-*proto*: What happened?

C8-*proto*: It's [sic] very deep for me.

P8-*proto*: And what happened?

C8-*proto*: I was crying, and I couldn't swim... It was too deep and I don't want to go all the way to the bottom.

P8-*proto*: So were you scared?

C8-PROTO: Yes

P8-PROTO: Why were you scared to jump into the pool?

C8-PROTO: I told [Aunt's name] I don't want to, but she said "Yes! Yes! Yes!" [Then the child imitates a crying sound]

P8-PROTO: [Giggled at her daughter's acting] Awww ...

Inversely, after the boy in family #2 incorrectly responded with "scary movie" for the *self-efficacy* prompt, the mother asked follow-up questions to guide the reflection process. However, this strategy did not yield any descriptive answers.

P2-PROTO: You were scared of a scary movie... were you scared when you're doing a sport?

C2-PROTO: Yeah!

P2-PROTO: What were you scared of? ... Remember?

C2-PROTO: [Long pause, no response]

P2-PROTO: You told me you were scared of a scary movie. Can you tell me a time when you were scared when you were playing?

C2-PROTO: [No response]

Scaffolding Using Examples

Examples can be a straightforward way for parents to help children reflect on their experiences ($n=3$). Previously, child #2 did not give a relevant answer even after his mother guided him with follow-up questions. However, after the mother responded to the same question, the child was able to respond immediately.

P2-PROTO: I remember when I was riding my bike and someone pushed me off my bike. And I fell. And I got gravel. And I had a big scrape on my knee [points at knee] and I had to go to the hospital. So that's something I remember... I remember that. Do you remember a time when you were scared when you are doing an activity?

C2-PROTO: Yeah!

P2-PROTO: When?

C2-PROTO: I'm still a new activity [sic].

P2-PROTO: Oh when you're doing new activity. Yeah, that can be a little scary.

However, examples did not seem to be useful for other families. In family #4, the youngest daughter did not answer the *enjoyment and parental support* prompt, whereas the older siblings gave irrelevant answers. Then, mother #6 responded to the question and asked the same question again to her children. While her answer could function as an example, her children did not respond to the question.

P6-PROTO: Well I like just being with you guys. I like us having fun. I like to see you smile. I like when you guys being silly. I like when we're making jokes, when we're having fun. *So what do you guys, what do you guys like?*

C6-3-PROTO (4 y.o.): [No response]

Scaffolding by Question Tailoring

To reduce the complexity of answering the reflective prompts, some caregivers tailored the prompt to make the question more accessible for their children. The mother in family #6 tailored the *enjoyment and parental involvement* prompt with additional details that enriched the question:

C6-2-PROTO (7 y.o.): What does that [physically active] mean?

P6-PROTO: When you're physically active. When we're out

maybe at the pool, at the park. Maybe up at the gym. *What do you like most when we're out together?*

C6-2-PROTO: Um [Looks up, pauses] When we're swimming!

C6-1-PROTO (9 y.o.): Me too!

In the interview, parents #2 and #4 suggested that the wording can be made more accessible by using familiar terms (e.g., *gym* or *played outside* instead of PA).

Other families tailored the question to match their personal experiences. For example, the mother in family #10 modified the question about swimming *self-efficacy* because her daughter has never been to a swimming pool.

P10-PROTO: Can you remember a time when you felt scared to jump into a pool?

C10-PROTO (3 y.o.): [Shakes head]

P10-PROTO: We have never been to a pool. What about the ocean? [...] Can you remember a time when you felt scared to jump into the water?

C10-PROTO: Yeah

Parent #12 also suggested a similar tailoring during the interview. Instead of the generic "Can you think of the last time you were active together", she suggested a more intimate prompt: "*Remember the time when we did this?*" or "*What happened when we did that?*"

In conclusion, our data shows a range of depth among children's responses to the prompt. This may be attributable to a number of barriers, which we will discuss in the next section. To help their children respond to the prompts, some caregivers guided their children's reflection using scaffolding strategies. However, given that not all caregivers used these strategies, our findings highlight opportunities for future systems to invite parents into the child's reflective process via features that encourage parents to engage in follow-up dialogue, to give examples, and tailor questions.

Barriers to Children's Reflection

In this section we will further elaborate on the barriers that emerged during our observations of children's reflection: low engagement, developmental stage, limited experiences to reflect on, and negative experiences.

Low Engagement

Some children ($n=3$) exhibited behaviors that suggests *low engagement* with the activity. They frequently moved away from the parents and sometimes refused to participate in the activity. For example, child #7 exhibited low engagement when his answer was unrelated to the activity:

P7-PROTO: Do you ever get scared when you wanted, when you want, when you want to jump to the pool?

C7-PROTO: [Utters something about a whale]

P7-PROTO: With a whale?

C7-PROTO: [Utters something about Spiderman & Peter Parker]

Developmental Stage

As young children are in the process of developing their ability to express their thoughts, some participants faced difficulties responding to the prompts. For example, the

mother in family #2 explained why her 4 years old son was able to answer the prompt after he heard her response.

P2-int: I think, um, I think he doesn't always know how to put everything into his own words. Still at this age. I think they're still kind of learning how to use language and how to make their thoughts and feelings into like words.

Limited Experiences to Reflect On

Some children do not have relevant experiences to reflect upon, thus prompting them to reflect on specific activities presented a challenge. The girl in family #10 had never been to a pool and the mother had to tailor the question. Similarly, the three children in family #6 had their first swimming experience a few months prior to the study. Their mother suggested that this is the reason why her children's response to the self-efficacy question was not very detailed:

P6-int: They've never [swim] prior to this summer, they've never learned. They never knew how to swim. We've never gone to a pool.

Negative Experiences

Certain reflections on personal stories—namely reflections on distressful and negative experiences—can be challenging for children and families. For example, as we described previously, the mother in family #8 had to scaffold the her daughter reflection process when responding to the *self-efficacy* prompt. During the interview, this mother further described how she helped her daughter answer the prompt because her daughter had a negative experience in a pool.

P8-int: She had to stop and think about it. And you know, I had to help her a little bit. [...] So I was like, “*Remember what happened?*” And then that's when she started remembering that she didn't want to get in and that she told my sister, “*She don't want to get in.*” But my sister was like, “*Get in.*” So she really started crying. So she didn't get in. [...] I guess you don't really think about what you don't like.

Parent #12 told us that her older son's father passed away while swimming. She expressed her concern about discussing difficult experiences with her child (her older son did not directly participate in the storytelling session):

P12-int: [His] father passed away from swimming, but um, it was, um. So you know, I, I feel like, um, like I don't want him to have a negative experience, but he definitely doesn't want to swim now. Like he was on the swim team and he doesn't want to swim. I don't know if he's made a connection?

These accounts show how reflection on personal stories are emotion-laden and highlights the need to determine to what extent personal stories should be incorporated during reflections. While reflections can springboard further conversation about how to address difficult issues [30], special caution should be taken to avoid unnecessary negative consequences. Our findings suggest that reflective systems should be careful when inviting user reflections, especially with families and children.

Furthermore, our data suggests that reflective prompts do not always encourage detailed reflection from children. In the

next section, we discuss how even brief child dialogue can impact caregivers' thinking and attitudes.

Facilitating Behavior Change Through Self-discoveries

In this section, we describe how caregivers engaged in PA-related reflection with their children. Our data suggests that the non-prescriptive and open-ended prompts facilitated self-discoveries of factors that correlate with children's PA: *caregiver behaviors* and *child's self-efficacy*.

Caregiver behaviors

The prompts encouraged some caregivers to think deeper about whether and how they are active with their children. For example, the mother in family #2 said that the *enjoyment and parental involvement* prompt helped her to think about the extent to which she was involved in her son's PA. Even if she frequently took her child to the park to be active, she realized that she could be more involved with her child:

P2-int: [The prompt is] making me realize, like, maybe I don't partake in things as much as I could when we go do activities together.

The social setting of the reflections supported the discovery of new insights. The mother in family #6 first discussed how, as she was unable to answer the *enjoyment and parental involvement* prompt, she realized she had not been active with her kids previously. She further described how her children's inability to answer the prompt was particularly striking, vividly conveying how she was rarely being active with her kids:

P6-int: It sparked a lot for me. I wish I could tell you. No, it really did. I mean, I've done studies, but this one really sparked a lot. The questions was really good, because even if they couldn't even answer the question, because it was—I mean, it was pretty simple for them to answer and they couldn't even relate or answer the question.

The accounts from P2 and P6 suggest that reflections can facilitate discoveries about one's behavior in the context of their role in their social environment. Furthermore, having the reflection in a social setting can elicit insights from people who have significant influence, such as spouses and children. When mother #8 asked “*what do you like most when you do PA together?*” during the storytelling session, her daughter said it was “*playing with you*”. This response engendered an affective reaction, as the mother immediately expressed her delight and hugged her daughter. In the interview, she described how having her daughter verbally express that affection was surprising and valued:

P8-int: She said she likes doing it with me and that's why she likes doing the activity. So that was really sweet. [...] It was a little surprising for her to say that she likes to do it because she's doing it with me.

These findings suggest that the one benefit of reflective interactions is the emotional connections that they engender. Furthermore, accounts from P6 and P8 supports the notion that reflection is not only an individualistic activity that takes

place in isolation; rather, it provides additional value when intertwined with social interactions [3].

Child's Self Efficacy

Our prompts did not didactically explain the significance of *child-related factors* (e.g., self efficacy) that affect children's PA. Instead, the prompts encouraged each family to inquire about past experiences, considering the ways in which factors that impact PA are manifest in their family. Most caregivers reported hearing responses from their children that were unsurprising ($n=7$). For example, one mother said:

P9-int: I guess I kind of knew it [the daughter's response] already. You know, her answer's not that surprising.

While some prompts elicit obvious responses, this does not suggest that future tools should avoid presenting users with such reflective springboards. For some parents, these questions seemed to support *consciousness raising* about the significance of child self-efficacy. For example, although her son's response to the self-efficacy question was not surprising for mother #3, she nevertheless became more sensitized to listening for his thoughts:

P3-int: I was wondering what, like what he was gonna say. Because I mean, he's had some, a couple moments of being afraid in the water.

Similarly, the process of *consciousness raising* seemed to take place in family #6. When the children gave brief answers to the *self-efficacy* question, the mother planned to have more conversations about this topic, suggesting her increased awareness of the importance of self-efficacy:

P6-int: At first I thought they would talk about the first time they were afraid going into the pool. How terrified they were. I thought they would talk about. But I guess that's another conversation I'll probably have with them later.

For mother #2, although the self-efficacy prompts were not questions she would typically ask, the prompt gave her a reason to talk about factors that affect her child's PA. She said that she can use her child's response to springboard conversations that support her son's self-efficacy. This mother specifically discussed using her personal story to drive these conversations:

P2-int: [Telling my story,] it's not something I always think to do. But that [prompt] was really helpful for me to say something. So he has a, he has a perspective on maybe like, "Oh, you're sometimes scared when you do new things?" Like, that [knowing that parents can also experience fear] is good to know. It gives them perspective, like, "it's okay".

Our data shows how caregivers were reflecting and how they discovered and gained insights about various factors that influence their children's PA. We will further discuss the significance of these findings in the Discussion.

Reflections to Nurture Family Identity

In this section we will discuss how broader, non-health focused family reflections can be a space to trace meaningful events, give clarity, and crystallize family history. This

notion of history can solidify the family identity and help people make sense of the events happening in the present [62]. By studying the value of general reflections, we can learn some lessons for how to guide health reflections. For example, parent #11 described how reflective prompts can help children to remember past events and solidify their identity by learning where they are from:

P11-int: It helps them [children] remember stuff that goes on, because sometimes you feel that they go through life and they don't remember certain incidents of stuff that happens. It gives, it helps them learn where they're from.

Grandmother #1 also values the remembering of past events. She suggests that reflection on the details of past events is a way to preserve their history:

P1-int: Well, details are history. They are the history. Remembering stuff is part of history.

Such reflections can incorporate interpretations of the meaning of personal events. Mother #12 emphasized this when she described the value of storytelling more generally:

P12-int: With storytelling it's you're, you're creating a story, but it's based on your own history [as a family]... [Stories], it's like something that actually happened, but then it's like an, an additional interpretation of what happened.

Furthermore, parent #11 suggests that reflections on past events can help younger generations to make sense of their lives by being more attuned to their family identity.

P11-int: [Remembering helps them learn] what they went through. Um, they're not blind by certain, um, certain stuff when they get older. They remember their experiences, so it helps them relate to certain stuff even more better.

One example was presented by the mother in family #9, who described a story that she used to motivate her child to learn to ride a bicycle in a park. She told a personal story about her aunt who taught her how to ride a bicycle at the same park:

P9-int: When we were about her age, my aunt took us there [to the famous park], walking. Um, and I remember riding and yeah, riding our bikes in [that park]. When we were younger. So you know, it's a good, good place. "Like we used to do this. You can do it, you know."

She further elaborated that she can motivate her daughter to learn to ride a bicycle by creating a link between her past experience and her child's current experience:

P9-int: [Just to let my daughter know] when we were her age we were doing, *you know*, kind of the same thing or learning to do the same thing.

Similarly, mother #2 felt that personal stories can be a space to discuss a shared affinity for activities, conveying how an activity she likes is something her child can also enjoy:

P2-int: I think kids love hearing what their parents like doing. [...] Like, "Oh, this is what I love, maybe you'll love it too."

These findings highlight how the retelling of past experiences is more than a mere recollection of facts. Stories

embody family history (P1, P11), values (P12), how they have overcome challenges (P9), and shared affinities (P2). Caregivers discussed the general value of storytelling for constructing family identity. In the next section, we discuss how such story-driven identity construction can be beneficially leveraged in a health behavior change context.

DISCUSSION

Our findings highlight how guided family reflections can encourage discussion and awareness of factors that impact health behaviors such as PA, the building of family identity, and challenges that arise. We conclude by discussing how reflective informatics tools can support storytelling within families, engaging the social unit in recollections of past experiences, and in so doing facilitating dialogue, thinking, and identity construction necessary for behavior change.

Reflection Experiences Within the Stages of Change

Motivated by work in reflective informatics [3], we examined how families reflect within the context of health. Caregivers in our study described how they learned and became increasingly conscious of factors that correlate with child PA: self-efficacy and parental involvement. This facet of reflection is described in reflective informatics as *breakdowns*: realizations that are surprising or in conflict with existing beliefs or knowledge [3].

To further understand how guided reflection can positively shift health attitudes and behaviors, we used the Transtheoretical Model (TTM—a widely used theory of behavior change) as an analytical lens [47]. The TTM states that individuals adopt behaviors through a series of stages, namely *pre-contemplative* (not thinking about change), *contemplative* (thinking about change), *preparation* (planning for change), *action* (engaging in the changed behavior), and *maintenance* (sustaining the behavior).

Parental support for child PA (e.g., via involvement) is a critically important behavior for encouraging child PA, and prior work has modeled the stages caregivers go through in adopting this behavior [2,65]. The TTM further conceptualizes *processes of change* as the activities and experiences that help people transition between stages [47]. Using the TTM to further analyze our data, we found that as caregivers considered the support they provide their children, their reflection activities were characteristic of TTM processes of change: environmental reevaluation, consciousness raising, and self-reevaluation.

Environmental Reevaluation involves a re-assessment of how one's behavior impacts their child's behavior [47], for example, how parental involvement can influence the child's PA. These environmental reevaluations took place in the *cognitive domain* (e.g., as P2 and P6 discussed the value of parental involvement) and in the *affective domain* (e.g., P8 realized that her daughter enjoyed being active with her).

Consciousness Raising is a process in which individuals become increasingly aware of the causes and consequences of a behavior [47]. Our data suggests that some caregivers

experienced consciousness raising as they became more aware of the significance of their child's self-efficacy (P2, P3, P6). Parental support is correlated with child self-efficacy—a strong predictor of child PA [61]. Therefore, raising awareness about self-efficacy as a beneficial consequence of caregiver support may be a step towards encouraging support behaviors.

Self-reevaluation involves “cognitive and affective reassessments of one's self-image” [47]—this process helps people reconcile how their behaviors (e.g., regular PA) align with their desired self-image. Our participants discussed how storytelling is a natural venue for nurturing and reflecting upon family identity (e.g., P9, P11, P12 in “Reflections to Nurture Family Identity”). As such, a promising direction for future work is to explore how technologies can help families retell past experiences, assessing how their behaviors align with the collective identity (e.g., shared values, history, and affinities). This process is important for instilling positive values around healthy behaviors and helping people envision themselves enacting those behaviors.

We did not measure *parental support* stage of change (i.e., parental readiness to support the child's PA, e.g., by being active with the child) [2,65]. As such, we could not triangulate how caregivers' reflective processes aligned with their parental support stage of change. Nevertheless, our data suggests how non-prescriptive reflection can engage individuals in important processes of change that can support transition between stages [47].

Prior work demonstrated how an educational game helped individual users engage in processes of change towards adopting healthy eating habits [22]. We build upon this research by showing how another form of interactive experiences—storytelling and reflections—can support processes of change within a social, family-relevant setting.

Processes of Change as a Model for Reflection

As our data suggests that individuals were engaged in reflections characteristic of processes of change in TTM, we suggest applying the *processes of change as a model for reflection*. That is, reflection can be designed to facilitate specific processes of change that are tailored to one's stage of change. The significance of tailoring has been widely documented in the domains of health interventions [42], persuasive technology [44] and technology-based PA intervention [19].

Our design implications are informed by PACE (Patient-centered Assessment and Counseling for Exercise), a non-technological TTM-based PA intervention [45]. The PACE program begins by assessing patients' readiness to change using a self-report measure. After a patient's stage is identified, a physician can provide tailored counselling for patient. PACE has been shown to facilitate increases in moderate PA among adults [8] and adolescents [46].

Utilizing the same procedure, reflective informatics systems for PA promotion can begin by assessing users' readiness to

change (e.g., using a brief validated survey). Once the system identifies the user's stage of change, it can begin presenting tailored prompts. We present design guidelines for such tools and examples of how these designs might be realized. Our guidelines are focused on parental support, a behavior that directly and indirectly impacts children's PA [61]. However, given that TTM is applicable to many health domains [20], future work should explore how stage-matched reflections can be applied to additional health-related behaviors.

Precontemplation Stage

Families in the precontemplation stage are not physically active and have no intention to be active. **Reflections in this stage should guide broad storytelling on past family PA experiences**—to help families become generally aware of the benefits of PA and consider a more active lifestyle [45]. Example prompts for this stage include:

Can you remember a time when you enjoyed playing together outside? How did you feel afterwards?

What do you like best about your mother/father/child playing with you outside?

Contemplation and Preparation Stages

Families in this stage are not physically active but are interested in being more active and may have made plans to do so [45]. At this stage, **reflections should guide more focused storytelling aimed at near-term future planning, reinforcing the benefits of PA and addressing PA barriers**. For example, families might tell stories about (1) activities that the family has enjoyed, as a springboard to plan regular exercise, and (2) how loved ones have supported them in the past and ideation around how they can provide future support. Example prompts include:

Can you remember a time when you enjoyed playing together outside? How can you do a similar activity together this week?

Name someone close to you who has cheered you on or exercised with you. How did she/he make exercise more fun? How can she/he help you again in the future?

Action and Maintenance Stages

For families who have been regularly active, **the goal of the reflection is to be more attuned to the health and wellness benefits they have experienced, identifying ways to get back on track when they missed their regular PA and building self-efficacy** [45]. Example prompts:

Congratulations! You've been regularly active as a family. How does regular exercise with your family make you feel?

What is an activity that you have become more confident in doing? How did you become more confident?

PACE encourages praise and positive reinforcement when individuals meet their stage-specific goals [45]. Therefore, when incorporating *gamification* [13] in such systems, virtual rewards for meeting PA targets are more appropriate for individuals in the Action stage. For individuals in Precontemplation, the goal is reflection on the benefits of being active and how they outweigh the cons. As such, the

virtual rewards may be more effective when rewarding such stage-specific reflections. Similarly, for individuals in the Contemplative or Preparation stages, the goal is to plan near-term PA and identify social support. Rewards in these stages should recognize the creation of plans to be active and identify sources of support.

In conclusion, future work should further explore the design of reflective informatics systems in which reflection is tailored based on users' stage of change. A fundamental focus for such tools must be accurately determining stage of change, which can be difficult using self-report measures. Indeed, we found a mismatch in our survey data: most participants self-reported a high PA stage of change but relatively low intention to be active in the next week. A meta review also found that self-report measures alone are unreliable for identifying stage of change [39]. Future work should explore how TTM-tailored tools can leverage behavioral sensor data to triangulate self-report measures.

Limitations

Using a low-fidelity paper prototype, our work aimed to understand how parents and children reflect upon their health-related behaviors. Understanding their experiences is critical for informing future work in reflective informatics. While a majority of the caregivers were female, this is reflective of the demographics of the community programs that we recruited from. Additionally, our study put more emphasis on the parental perspective. More work is needed to explore children's perspectives on reflective systems, and how needs and preferences vary across age groups.

Rates of family reading are lower among low-income and racial/ethnic minority families [36], which may present a challenge in generalizing our design recommendations. However, in our sample of primarily racial/ethnic minority families, many of whom are low-income, participants' enthusiasm with our prototype suggest that parents may enjoy reading to their kids, but lack the time or facilitation. Novel storytelling tools may provide compelling aid that can help them to overcome barriers to reading.

CONCLUSION

Stories are a powerful medium for helping families reflect on the past, construct their collective identity, and envision future behaviors. Using a low-fidelity prototype, we explored how caregivers and children engage with a tool that prompts health-centered reflections. Our findings suggest that during these reflections, individuals can engage in consciousness raising, environmental reevaluation, and self-reevaluation—critical processes of change within the Transtheoretical Model of behavior change. Future work should further examine how reflective informatics systems can be designed to encourage processes of change, particularly evaluating the efficacy of such tools longitudinally, in different domains of health, and exploring how varying family structures, demographics, and other factors impact engagement with such tools.

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