Family Health Promotion in Low-SES Neighborhoods: A Two-Month Study of Wearable Activity Tracking

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ABSTRACT

Low-socioeconomic status (SES) families face increased barriers to physical activity (PA)—a behavior critical for reducing and preventing chronic disease. Research has explored how wearable PA trackers can encourage increased activity, and how the adoption of such trackers is driven by people's emotions and social needs. However, more work is needed to understand how PA trackers are perceived and adopted by low-SES families, where PA may be deprioritized due to economic stresses, limited resources, and perceived crime. Accordingly, we conducted a two-month, in-depth qualitative study, exploring low-SES caregivers' perspectives on PA tracking and promotion. Our findings show how PA tracking was impacted by caregivers' attitudes toward safety, which were influenced by how they perceived *social connections* within their neighborhoods; and cognitive-emotional processes. We conclude that PA tracking tools for low-SES families should help caregivers and children to *experience and celebrate progress*.

Author Keywords

Personal health informatics; Wearables; Physical activity trackers; Self-monitoring; Family; Caregivers; Low-socioeconomic status; Places; Neighborhoods; Crime.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Obesity is a health epidemic that affects 17% of children and 35% of adults in the United States [35] and increases the risk of diabetes and cardiovascular diseases [39,52]. Interventions designed to prevent and reduce obesity are most effective when they focus on the family environment, where healthy behaviors can be supported at an early age [16]. As obesity disproportionately impacts low-socioeconomic status (SES) families [35,46], targeted interventions are needed to support healthy behaviors within these populations where resources are often scarce [8,23].

Regular physical activity (PA) is critical for achieving a healthy body weight [45] and the emergence of health sensors in mobile and wearable technologies has created new opportunities for PA promotion through self-tracking in the family setting. For example, *Spaceship Launch* and *Social Family* are two self-monitoring tools designed to encourage children and adults to be more active [20,42]. This work has demonstrated how social influence in the family setting can help children and caregivers to be more physically active. Indeed, prior work has shown the importance of social experiences within self-tracking, especially in the general population. Work by Rooksby et al. shows that people do not just dispassionately use self-tracking tools to collect data and direct future actions [40]. Rather, these self-tracking practices are motivated by people's goals and emotional needs in the context of their social and personal lives [40]. Additionally, social interaction during self-tracking can help sustain engagement with such tracking tools [27]. However, while personal and social goals can bring people into self-tracking, Elsden et al. suggest that data from self-tracking tools sometimes lack details that are meaningful, such as the emotions and the social connections that people had when they exercised [11].

Collectively, this prior work characterizes self-tracking use in the general population and highlights critical design requirements for self-tracking technologies. However, low-SES families face multiple PA barriers, such as low perceptions of neighborhood safety, reduced access to PA facilities, the cost of PA programs, finding childcare during PA, and limited time due to burdensome employment [8]. As such, PA is often deprioritized given other pressing needs and short-term life goals. Therefore, given that PA tracking is interwoven with people's life goals [40], more work is needed to understand how PA trackers can be incorporated into the life of families in low-SES contexts, as well as the emerging emotional and social experiences.

Guided by this prior work, we conducted a study to answer this overarching question: *How does socioeconomic context shape caregivers' perceptions and use of current PA tracking tools?* We conducted a qualitative study with 11 caregivers and nine children from nine families living in predominantly low-SES neighborhoods to understand their adoption of self-tracking tools—and to characterize current practices and opportunities for future innovation.

Our findings help characterize caregivers' perspectives on family PA tracking in low-SES contexts. First, we contribute an understanding of how perceived crime can limit family PA tracking use and how the depth of social connections in one's neighborhood can affect feelings of safety. Second, we describe how PA trackers impacted caregivers' attitudes and behaviors, as well as their emotional responses while self-tracking. Understanding caregivers' perspectives is an important step towards establishing design requirements for family PA tracking applications, given that caregivers play a major role in shaping their children PA [17]. Based on our findings, we suggest that future work explore three processes that may support PA tracking use: *surprising discoveries, bodily experiences*, and *social mindfulness*. Finally, guided by Attribution Theory, we present design recommendations for how PA trackers can help caregivers to *experience and celebrate progress* with their children.

RELATED WORK
Socioeconomic Impacts on Physical Activity
Low-income and racial/ethnic minority families face multiple barriers to sustaining a healthy weight (e.g., economic stresses and reduced access to PA opportunities), which underscores the need for health intervention strategies that meet the specific needs of low-SES families [23].

Indeed, prior work has shown that socioeconomic status is strongly associated with adults and children's participation in PA [17,51]. For example, one's physical environment (e.g., parks, health clubs) plays a powerful role in supporting or inhibiting PA [18,51]. One area of research has explored the relationship between safety, crime, and physical activity levels. While research suggests that higher crime reports are not associated with PA levels [21,55], other research shows that perceived neighborhood safety is associated with being active [3,4]. These findings show the nuanced relationship between PA and crime, suggesting that beyond objective accounts of crime (such as crime reports), the subjective experience and perception of crime may play an especially important role in PA. Furthermore, this prior work suggests that parental perceptions of outdoor safety play an important role in children's PA, because time spent outdoors has been consistently associated with higher PA among children [14]. Collectively, these findings warrant further research unpacking the relationship between PA and how families perceive of their physical and social environments.

Gustafson et al. suggest that PA interventions should also address modifiable social factors, such as parental support [17]. Indeed, a vast evidence base shows a strong positive correlation between parental PA support and child PA level [17,50]. This evidence suggests the need to design PA interventions that help parents and caregivers support their children to be more physically active and to cope with environmental barriers that they face. Our work explores how PA tracking tools can provide such assistance, with a particular focus on the impact of physical and social environments on technology adoption and perceptions.

Physical Activity Promotion Technologies
While there is a wealth of research on technology-based PA promotion, particularly in the context of individuals, very little work has examined how technology-based PA promotion tools can be used in the family setting. One notable system is *PiNiZoRo*, a GPS game in which parents and children are encouraged to walk together outside by exploring a neighborhood map augmented with game characters [48]. Another tool, *Spaceship Launch*, is a gamified PA dashboard in which parents and children are invited to be active together while wearing Fitbit activity trackers, to win virtual rewards [42]. When using this tool, caregivers appeared to value in-game competition with their kids because the social interactions helped satisfy the psychological need of being connected with their children [42]. Schaefbauer et al. also noted the value of family interactions when evaluating *Snack Buddy*, a digital tool for family members to track their snack consumption [44]. The study found that in-person family interactions mediated by the system helped increase families' health awareness [44]. These projects highlight the value of social interactions in health self-tracking, especially in family settings.

In addition to being influenced by social factors, self-tracking is affected by people's emotions. Rooksby et al. suggest that individuals do not just dispassionately collect personal data and act upon it [40]. Rather, self-tracking is a practice that is situated within people's life goals and emotional needs [40]. Improving one's PA is not simply about increasing one's fitness level, but also about supporting "*the emotionality, the hope, and the fun that people have*" while being active [40]. Elsden et al. also explored the emotionality of self-tracking, documenting how the affective dimensions of people's lives are often not captured in self-tracking tools [11]. While the arguably objective depictions of one's life provided by many self-tracking tools can be very detailed (e.g., step counts over time), these data lack key details that matter to people [11].

Indeed, decades of health research have shown that self-tracking can help individuals to achieve desired behaviors [22]. However, individuals are also affected by a multitude of personal, social, and environmental factors as they seek to become more active. For example, multiple studies have shown that children are more active when their parents are supportive of their PA—with encouragement, involvement, and facilitation as the most important forms of support [17]. Furthermore, a wealth of evidence shows that PA is also correlated with support from friends and family, self-

efficacy, enjoyment, the physical environment, as well as socioeconomic status [17,18,43,50]. These complexities often are not fully captured by the current PA tracking technologies which, at their core, are built to capture and depict objective measures of PA (e.g., step counts). Moreover, creating technologies for low-SES populations often necessitates addressing nuanced design challenges. Such challenges include user interface design considerations [5] as well as societal attitudes that can inhibit technology use [9]. As such, more work is needed to understand (1) how PA trackers satisfy the emotional needs of caregivers and their children, and (2) how PA trackers become interwoven with families' social and physical environments, especially in low-SES contexts. By characterizing some of these processes, our work will help inform the future design of more holistic health promotion tools that support people's social and emotional needs as well as their aspirations.

METHOD
We conducted a two-month qualitative study to understand the experiences of low-SES families using PA tracking technologies. This project was done in collaboration with two community organizations. One of the authors is a community leader who was involved in the study design, data collection, and analysis [53]. Our University's Institutional Review Board approved the study protocol.

Study Design and Recruitment
We recruited families with young children (5-11 years) from family-centric community organizations in a metropolitan city in the northeast United States. Families were eligible to participate if they were comfortable with spoken and written English, owned a smartphone with Internet access, and lived in a predominantly low-income area.

We conducted in-depth semi-structured interviews in three sessions: at the beginning of the study, one month, and two months after the initial meeting. At the beginning of the study, adult and child participants were given Fitbit Alta and UNICEF KidPower wristbands, respectively, to wear for the duration of the study. The bands were selected after we reviewed consumer PA trackers in terms of their accuracy [13], ease-of-use, comfort, on-band display, and battery life. We also looked for trackers that were tailored to capture the attention of kids, as well as adults. Upon study completion, caregivers received a US$100 gift card.

Data Collection and Analysis
In the first session, we acquired consent from both the caregivers and children. Then we asked caregivers to fill out a survey to assess their PA frequency [33] and child's PA level [32], as well as demographic information. After that, we conducted the first semi-structured interview with the caregivers and children to assess baseline PA attitude and perception. Finally, we gave the Fitbit Alta and UNICEF KidPower PA trackers to the caregivers and children. We helped families set up the accompanying Fitbit and KidPower smartphone apps and briefly explained the

features of each. Families were asked to review their PA tracker data at least 10 minutes per week.

One month after the initial meeting, we conducted an in-depth semi-structured interview to assess caregivers' and children's perceptions of their PA and their experiences with the activity trackers. Finally, two months after the initial meeting, we conducted the final interview. The median durations of the first, second, and final interviews are 27, 43, and 51 minutes.

Interviews were conducted at participants' home or in community centers of the participants' preference. Audio recordings of the interviews were transcribed verbatim. The authors reviewed the interview transcripts and identified preliminary emerging themes; these initial insights were used to refine the semi-structured interview guides used in subsequent interviews. Once a theme began to reach theoretical saturation, we further fine-tuned the interview guide to unpack related themes.

In the first interview, we discussed the caregivers' and children's PA attitudes and perceptions. We also asked about the barriers that caregivers may face to support their children to be active. In the second interview, we continued to probe into caregivers' attitude and perception towards PA as well as their experience using PA trackers in a family setting. We asked how they reviewed their PA data and if these data support them in being active. We also probed how barriers specific to low-SES families affect their PA. In the third and final interview, we further probed how caregivers overcame the challenges related to crime, safety, and parenting in the context of PA tracking use. More specifically, we asked how the features in the PA trackers (e.g., PA reminders, PA nudges) impacted their family's PA, given the crime barriers that they face. Our focus on PA tracking in low-SES families led us to explore themes related to specific interactions with the devices as well as caregivers' perspectives on family PA more generally.

We qualitatively analyzed the interview transcripts using inductive thematic analysis [49]. The first author conducted open coding on the transcripts and clustered the codes to develop the emerging themes. Throughout the analysis process, the first author met regularly with other authors to refine the themes.

Participant Overview
We recruited 11 caregivers and nine children from nine families from May to June 2017. The median age of the caregivers was 36 (*IQR*=19) with a majority of them were female (*n*=9). For the child participants, the median age was 8 (*IQR*=4.25) and most of them were female (*n*=8). All caregivers self-identified as African-American and one also self-identified as Latino. The median household income was $22,596 per year or less. Eight caregivers were single, and the median number of children in the household was two. Most families were eligible for the state's need-based health insurance program, which provides insurance benefits to

low- and moderate-income families (*n*=7). Most caregivers self-reported their highest level of education as some college or vocational training education (*n*=7). All families in the study lived in lower-income neighborhoods, where the median income is less than the city's median.

The United States Department of Health & Human Services recommends that adults engage in 150 minutes a week of moderate-intensity PA; for children, the recommendation is 60 minutes of PA a day [45]. At baseline, our participants' median PA levels were lower than these recommendations. Caregivers self-reported a median PA level of three 30-minute bouts in the last week. The median of children's PA was five days with 60+ minutes of PA in the past seven days.

RESULTS

In this section, we discuss caregivers' experiences while using the PA trackers with their children. Using the PA trackers as a probe, we gained caregivers' perspectives on wearable activity tracking specifically and family PA more broadly. Our findings provide a rich picture of caregivers' values and experiences. These insights are needed to inform the design of future tools for low-SES families, given that caregivers' attitudes and behaviors are significantly correlated with children's PA [17]. Specifically, we describe phenomena that are both external and internal to the body when using PA tracking tools. First, we will describe caregivers' perspectives on the world external to the body—the physical environment—specifically the presence of crime, its implications for family PA, and PA trackers' role in this context. Then, we discuss caregivers' internal experiences, namely their cognitive, emotional, and physiological engagements with PA tracking.

Places as Realms of Trust

Prior work shows that neighborhood crime can negatively impact PA participation [18]. Given that all families in this study live in neighborhoods with 14-37% higher crime rate than the city's average, we examined how families adapted PA trackers into their living situations. P10 described how she ignored the reminders from the Fitbit app because being outside could pose immediate safety risks:

> P10: I ignore it [the reminder]. I'm like *okay*. When [the Fitbit app said] like, "*You have, like, 244 more steps*." Okay, let's see if I can walk in the house, but as far as getting out outside, that would be my last walk.

This quote illustrates how caregivers' concerns around crime can limit the efficacy of PA trackers, and led us to explore caregivers' safety concerns in greater depth. Throughout our interviews with multiple caregivers (*n*=9), we learned how crime and safety concerns are present in their neighborhoods in the form of shootings, sex offenders, drug abuse, gang activities, and unleashed dogs. While most caregivers did not reflect specifically upon the intersection of PA *tracking* and crime, they discussed at length how crime is a significant problem that they face when contemplating PA for their family. Their accounts help underscore how crime concerns

in low-SES neighborhoods may impact the efficacy of PA tracking tools that encourage users to be active outside.

Yet, while caregivers' discussions of crime may suggest hopelessness, they also emphasized that they "*can't live in fear*" (P11). For example, P8 said:

> P8: We're not in the greatest of neighborhoods. Um, there's shooting all around us. But you can't blame it on the rain. You're either gonna get out and exercise or not.

Here P8 suggests that while the risk of being exposed to crime is prevalent, it is up to the individual to be physically active. In P10's quote above, while she emphasized the extremity of the risks, she also acknowledged other means of reaching her PA goal (i.e., walking inside her home). Therefore, rather than being subjected to crime, P8 and P10 seem to exhibit a feeling of control over their families' wellbeing. This is a theme that emerged from almost all caregivers in the study when we asked about their comfort having their family being active outside. They suggested this notion of control when they described ways to stay safe while being active outside: by (1) *circumventing the risks* (e.g., by exercising indoors or outside of the neighborhood) and (2) *being mindful of the community*.

The theme of *being mindful of the community* suggests how caregivers see their neighborhood not just for its physical attributes, but also the social connections that are in place in terms of individuals whose presence gives or does not give assurance for their children's safety. When P1 described one part of his neighborhood that he considered unsafe, he also described the individuals who live in a particular house and how they were associated with criminal activities:

> P1: That's the corner over here that had a problem. We stay away from that corner and watch out for that corner, because it's been, it's changed a lot since we've been here, that house. [...]. It did get raided like twice a year.

P1 also described locations that he considered safe because a person that he trusts lives there:

> P1: The lady down on the corner, her yard. Um, the house right here, [my daughter] goes over here and play with their, their daughter. They have one daughter she plays with. Um, she's not allowed to go in the house, but she goes. She can go over to the yard and whatnot and play. Um, [my son] goes, goes more around the block and whatnot. But he's not allowed to carry her around the block with him.

This perception of safe territories may be related to the length of time P1 has lived in his neighborhood ("*We've been here ten years*"). Similarly, P9, who grew up in her current neighborhood, also said that she felt safe having her children play outside given the crime concerns because her neighbors will look out for her kids when P9 is inside:

> P9: You have good days, and you have bad days, but most likely. Like I'm in here, my daughter's out there. So, like, "*it takes a village to raise a kid.*" [...] I still have people that's, even though I'm not out there, they'll still look out for my kids. Vice versa if their parents ain't around I'll still look out you know.

Moreover, she described how this responsibility is reciprocal and how her trust network is a result of an accumulation of shared history over the time she spent in her neighborhood:

> P9: I have family out here. I have friends, close friends out here. [...] People I grew up with, people that's family, who I call family. [...] But I won't let somebody I don't know [watch out for my kids], you know.

She then emphasized that she did not trust everybody in her neighborhood, but only a set of people whom she refers to as "family". These findings suggest that the social connections that individuals had developed with their neighbors helped give them a sense of trust. In contrast, P3 relies on her older daughter and her mother who lives on the same street to look out for her children.

> P3: We all watching them. You know, they either over there or they're over here.

When asked if she would feel comfortable having her kids play outside if her family were not present, P3 said, *"I don't think so. Uh-uh, because you know, you always need extra eyes."* P3's uncertainty about non-family neighbors looking out for her children was shared by P8:

> P8: Oh no. I take care of [my children] on my own. Uh-uh. [...] It's not so much what someone else is gonna do. It's that I love my child. I love her. You know what I mean. If you love somebody, you cherish it.

It may be that P8 trusts her neighbors less because she moved into her home less than one year before the interview. However, P3 had lived in her neighborhood for 20 years yet she is still uncomfortable trusting her neighbors to look out for her children. These sentiments suggest that the notion of trust was not just a function of time but also the social connections that people had in their neighborhoods. Some families trusted some of their neighbors (P1, P9) to care for their children's safety and others only trusted their relatives (P3, P8).

This theme of locations defined through social contacts that one can or cannot trust resonates with the notion of *realms* in urban sociology [25]. Realms are social spaces or social territories within physical locations. In other words, realms describe the density of social relationships that are present in urban locations. *Public realms* are constituted of individuals who are co-present in a physical location and are strangers to each other, whereas *private realms* are composed of individuals connected by kinship and personal networks. The third form of realms, *parochial realms* are "characterized by a sense of commonality among acquaintances and neighbors who are involved in interpersonal networks that are located within 'communities'" [25]. We will use this concept of *realms* to further describe the caregivers' perception of safety, places, and communities.

While introducing PA trackers can lead to uncomfortable feeling for families who live in neighborhoods with a high perception of crime, caregivers have a sense of control that helps them cope with such concerns. More specifically, some caregivers are mindful of their neighborhood and leveraged the private and parochial realms—social connections that are present in their neighborhoods—as territories that are deemed to be safe. Realms, by their nature, are negotiated through shared histories [25], which explains why P1, P3, and P9 felt safe having their children play outside because they have private or parochial realms (e.g., relatives and neighbors) that they trusted though accumulations of social interactions. Such realms carry the feeling of safety through the social connections that were understood as caring for each other. In other words, a *safe realm* is a physical place with social connections that give a feeling of safety.

The emotional value of safe realms was suggested by P3 when she appeared unsettled while describing a shooting incident from the day before the interview. She described her concern that the safety of her realm was punctured:

> P3: Yesterday, was a shooting down the street [...]. And I was like, *"Oh, my God."* [...] It's just getting too close to home, you know. That's like not even, that's somewhere where [my family] walk. We walk around that block. That's our block, you know. So, we walk up the hill and come down, come around. You know. It's just getting too close to home that's all. They need to take that somewhere else."

Later in the interview, P3 said that she still feels comfortable having her daughter to play outside. This suggests that while P3 felt her realm has become less safe, the shooting incident did not fully shatter her construction of her safe realm. This may explain how some caregivers felt resilient even when facing the disempowering narratives of crime.

In contrast, P10 (who lives in the same neighborhood as P9) felt the threat of crime intensely. While P9 was comfortable with having her children play outside because her neighbors are "*people who I call family,*" P10 did not want her children to be outside at all because she has a different view of her neighborhood:

> P10: I know like two girls in the building and maybe another girl from my kids going to school, but as far as like people in the neighborhood? No. [...] I just feel like we have to live here and you know, the stuff that goes on I wish my kids didn't have to, you know, experience it.

However, P10 also suggests that one of the reasons she restricts her children's interaction with individuals in her neighborhood was to show a world that she felt was more resonant with her aspirations of her children's future:

> P10: You have to show them different if you want them to be different. If you show them that all it is boys standing out here on the corner doing you know, whatever they're doing. You know, then my sons think this is the way they got to be. Hanging with the boys out here. You know, if [I] take them out, show them different stuff then they, when they get older they can be like, *"Oh, I can go here, because my mother took me here."*

It seems that P10 did not have the social connections with her neighbors with the intensity and density that allows her to feel comfortable letting her children play outside. However, P10's account suggests that the decision to limit

her children's social interactions in her neighborhood was also influenced by her aspiration to show a world that she deemed more suitable to shape her children's future.

These findings suggest that the fear of crime can limit opportunities to grow social connections and affect the development of realms. In turn, limited realms can inhibit individuals from developing further social connections. Furthermore, the meaning of safe realms was understood by the caregivers in their own unique ways and influenced by caregiver aspirations for their children.

Dourish described how realms are products of social interactions within physical places [10]. Furthermore, technology-mediated interactions introduce new ways to give meaning to existing physical places, thus providing opportunities for the production of realms [10]. This phenomenon was exhibited by P3 when she was exploring new places while wearing her PA tracker. Her experience suggests that she engaged herself in the production of realms—social spaces—for herself and her family. She discussed how she met new people and learned new information to support PA:

> P3: We [me and my daughters] meet people and then oh. "*You know there's a bike shop around the corner that can help you fix that.*" You know, when you get out and meet people they tell you different things that's going on, you know, in your area. There was an event two Saturdays ago in the park over there. We was like, "*Oh, this is nice.*" We went over there just playing and eating and everything, jumping around, bouncing balls. They was having a little basketball competition. It was like, "*Huh, see what happens when you get out? You learn stuff about your neighborhood. You learn stuff about people.*" [...] Yeah, it was surprising that we was like, "*Okay.*" Yeah, we didn't know.

P3's experience shows that being open to new contacts and places facilitate the production of new realms where caregivers can learn about new PA opportunities.

In conclusion, our interview data suggests how caregivers' perception of crime can limit the efficacy of PA trackers' reminders and nudges, and that it was the depth of social connections in a neighborhood that helped caregivers feel comfortable with their children being active outside. Caregivers in our study negotiated the concept of safety through considerations of the social attributes of places. This insight shows that understanding how caregivers conceive of places and their family's ability to be active within those places is critical, especially for technologies that encourage PA in environments where higher crime rates necessitate increased consideration of the safety of one's family.

From Surprising Discovery to Attribution to Self
While in the previous section we discussed how families negotiated and perceived the spaces that they inhabit (i.e., the world external to the body), our findings also highlight important caregivers' experiences that were internal to the body. These encounters included: cognitive, emotional, and physiological experiences that arose as caregivers 1) determined how to attribute the locus of the success and

perceived failure presented on their PA trackers, 2) accumulated insights from surprising discoveries made through activity tracker data, and 3) had bodily experiences that helped to create these surprising discoveries.

Attribution to Self and Resulting Emotional Responses
While wearing the PA trackers, caregivers explained that they became more active because of their capacities and abilities, with some help from the PA trackers. For example, P8 said that the combination of her determination to be active and the PA tracker enabled her to be more active:

> P8: You know, [I can achieve my PA goal because of] my personal strive to do that, you know. Because without me, what would have the Fitbit? And without the Fitbit, what would have me? But yeah, it takes two I think.

P8 also said that the PA tracker encouraged her to self-challenge herself ("*Okay. I could do two [hundred] more. I can do three [hundred] more*"). P5, who also attributed his success to his determination plus the PA tracker's help, also described how the data encouraged him to challenge himself:

> P5: Just my mindset. My mind being set on '*I want to be active*' [...] The app helped. [...] The data that you see on the app for me, again, it was more ... it was encouraging to push myself to do double of what I was doing.

These accounts show how PA trackers help invite individuals to challenge themselves to be more active. Participants also said that the experience of success gave them a feeling of pride and satisfaction; for example, P8 ("*I can actually, um, be proud of myself. You know, I can look and I can congratulate*") and P5 ("*It made me feel good*").

Our findings highlight the relationship between attributing success to oneself, the positive emotional outcomes that emerged, and how the experience was mediated by the PA trackers. For example, P5 described how the notifications from the trackers when he met his goal made him feel good:

> P5: [When I met my goal, I felt] like I just won a gold medal. It's definitely good for myself. The app served as a quick reminder, like "*You did this.*"

Furthermore, the PA tracker confirmed that he accomplished his goal. P8 also suggested that one of the roles of the PA tracker is to confirm her accomplishments:

> P8: If I don't do what I set my goal, what I set my goal to do, then my Fitbit's not going to give me that reaffirmation.

These accounts suggest that one role of PA trackers is to confirm fitness progress, and the confirmation of this progress led some caregivers to attribute the progress to themselves. This attribution to oneself led the caregivers to experience positive emotional outcomes.

Some caregivers did not end up becoming regularly active during the study. P4 wanted to be active three times a week. As she did not meet her goal, when her PA tracker sent her reminders to walk she experienced self-blame:

P4: It tried to give me reminders. But then I think it was making me feel more guilty. It's like, "*Oh, I'm not going anywhere and it says, 'take me for a stroll.'*" So I don't do that. "*Take me for a stroll*," or something like that. And I was like, "*Oh, I can't do it now I'm tired.*"

Similar to P5 and P8 who said that the PA trackers confirm their fitness, early in the interview P4 said that the tracker was motivating because it gives a perspective on her PA:

P4: [The tracker was motivating] because I can just see like what I'm doing. Like I'm not just like, "*Huh, I wonder if I lost any?*" Like it actually, [...] It was telling me something.

P4 saw that she does not need to wonder whether she has been active because the PA tracker will tell her. She also emphasized that her tracker is more accurate than her daughter's tracker:

P4: I don't think hers is accurate. Because sometimes it tells you, "*She's at 10,000 steps*." I'm like, "*You didn't do 10,000 steps. Like I moved more than you did,*"

This quote suggests that P4 valued the "truthfulness" of PA trackers. Therefore, when P4's tracker indicated that she was going to miss her goal, the tracker also confirmed her failure. This confirmation seemed to lead her to attribute the failure to herself and made her feel guilty. P4 then suggested that the reminders should be modified to make her feel better:

P4: [I would feel better if the Fitbit] say, "*Oh, good job doing 20 steps.*" [...] More encouragement versus just a reminder. Like it could say, "*You're almost there.*" To me that one would make me feel better. Maybe a sound that will say, "*Let's go for a walk. All you need is 10 minutes. You can do it. Get out of the house.*"

It seems that P4 wanted the PA tracker to confirm her efforts ("*Good job doing 20 steps.*"). Furthermore, she may suggest that the PA tracker needs to break down the tasks to make it sound more achievable (i.e., a walk, 10 minutes, start with getting out of the house), which may also suggest her need to have a feeling of control over her PA.

Surprising Discoveries
Another aspect of reviewing PA tracker data is experiencing *surprising discoveries* about one's state of fitness. Indeed, the notion of surprise during self-tracking has been demonstrated in prior work [2,6]. For example, Choe et al., described this as *contradiction,* where "collected data contradicts existing knowledge" [6]. We use our findings to further unpack in what ways individuals experienced surprise.

Our data suggest that surprising discoveries about one's capacity can lead caregivers to *self-challenge* themselves. For example, P8 was surprised by her PA tracker data because she did not realize that she can walk that much. This discovery led her to *self-challenge* herself to walk more.

P8: You look at it and you're like, "*Oh, wow.*" I didn't even realize the number of steps and miles I did in just a regular day. You know, and then looking at that I'm like, "*Okay. I could do two more. I can do three more.*" You know, so it's an incentive. It's a motivation, you know.

P7 was also surprised by her PA tracker data and similarly challenged herself to be more active:

P7: One thing I learned new was that I, how many miles I can walk. [...] Because I'm not really a walker. But since I had this watch I've been, you know, walking more.

P7 was surprised when she found out how much she can walk. The surprise led to an increased awareness about her competence and a disconfirmation of her previously held identity as a non-walker. This interplay of insights and self-reflection led her to walk more.

Surprising discoveries can also bring individuals to reflect on their experiences. For example, P10 was surprised that she met her goal early in the morning ("*It was only like 10 o'clock and it went off like I reached my goal. I'm like, 'What was I doing?'*"). She explained how that experience was unexpected because she usually reached her goal after she gets off from work as a street cleaner. This surprise invited her to reflect on her activities that day:

P10: So, I'm like, "*Well, what was I doing today?*" I must have been doing like a lot of walking and didn't like really realize it. [...] I think I just wasn't in the truck like as much. [...] I think we had like a lot of work that day. So it's like just I was really busy.

This surprise encouraged P10 to think about her activities and the intensities of her activities that had contributed to achieving her step count goal early that day. For P3, she was surprised to learn that bowling takes a lot of steps:

P3: Yeah, bowling, you do a lot of stepping too. Yeah, it was [surprising], I was like, "*Oh, okay.*" [...] The only thing that's not a lot of steps is the movies.

P3's quote suggests that through surprising discoveries, she became more aware of activities that are more physical and, perhaps, more healthy.

So far, we have discussed how *surprising discoveries* led caregivers to self-challenge themselves and be reflective of their activities. The lack of *surprising discoveries* can also lessen the usefulness of these PA data. For example, P10 was very interested in the tracker during her first month. However, at the end of the second month she lost interest because she experienced *saturation*—seeing the same PA pattern over and over again:

P10: It starts to become boring. At first, it was like, yeah, let me see how many steps I can walk. You got a whole month, so it's like, you see the different steps you're taking all the time, but by the second months, it's like, it's the same thing. It's not switching up. Open the phone to see everything you did, but it's not like it was anything different from yesterday.

Similarly, P1, who was a gym coach, was not surprised when he saw the PA data. He suggested that the tracker does not have a significant impact on him because he already has an idea about his physical activity behavior ("*I know I'm active. I know I'm busy.* [...] *I know who I am. I know what I'm doing, so I have an idea already.*"). These accounts further underscore the role of *surprising discoveries* in helping PA

tracker users to self-challenge themselves and be reflective about their activities.

Bodily Experiences

Accounts from the caregivers also suggest that *surprising discoveries* are related to their bodily experiences. For example, while P5 is aware of how calories are consumed and burned, having the activity tracker show him that he burned a significant amount of calories was surprising:

> P5: Through health class, I knew that obviously, we control the amount that we take in and the amount that we're burning. Um, but to actually see some sort of data being captured from what I did for the day. It was definitely like a big surprising eye-opener.

In particular, P5 described that it was not just the data itself that was surprising, but also the fact that the data represents what he did, his activities, and his body movements. We saw this practice of 'triangulating' data and body throughout the interviews and how it was motivating. For example, P8 described that while the activity trackers said that she walked a lot, the walking did not make her body feel tired:

> P8: You're like, "*Oh, well, it wasn't that tiring.*" So I can get out and I can actually do more.

Moreover, upon realizing that the walk was significant and not particularly tiring, P8 was encouraged to self-challenge herself. P3 also suggests that she valued the ability to tie the activity tracker data to her bodily feelings. She described that her preference was to view step counts versus the miles she had walked because the former allows her to understand her progress in terms of the feeling sweating or fatigue:

> P3: I just like counting my steps. I don't know. The places, I've been everywhere around here. So, so it's not interesting to me. I want to know, *like*, the steps, [they] make me feel like, "*Oh, I'm losing weight. Okay, oh, I'm sweating or I'm tired.*"

These findings suggest how bodily experiences are meaningful for caregivers to make sense of their tracking data, perhaps because the felt properties of in-body sensations can embody abstract PA tracking data. In the next section, we will discuss the implications of our findings in designing family PA tracking in low-SES context.

DISCUSSION

The findings presented in this paper help characterize caregivers' perspectives on PA and PA tracking, within the context of low-SES neighborhoods. While monitoring their fitness, some caregivers experienced the feeling of *attribution to self, surprising discoveries*, and *bodily experiences*. Furthermore, as the majority of our participants lived in neighborhoods with higher crime rates, they described the places they inhabit in terms of the *social spaces* in which they are comfortable being active within.

Indeed, PA tracking use cannot be separated from the wearers' external physical world and their internal cognitive, emotional, and physiological processes. Furthermore, the physical world limits and broadens the scope of PA tracking use and this is affected by the depth of social connections

that the wearers' have in their community. In this section, we will further crystallize our emergent themes by integrating findings from prior work. We present design directions for further examinations of how PA tracking tools can be made engaging for caregivers and children.

Attribution and Emotional Responses

Our interviews showed that some caregivers attributed the outcome of their PA tracking to their perseverance, determination, and effort (or the lack thereof)—with the PA trackers playing a role in confirming the outcomes. Understanding these experiences is critical when designing PA promotion tools because learning about success through the PA trackers led some caregivers to challenge themselves to be more active, while learning about failure evoked self-blame in others. Using Attribution Theory as an analytical lens, we will further explain these phenomena.

Attribution Theory describes how individuals explain the causes of events or outcomes [54]. Three causal dimensions have been studied in this body of work: internality, stability, and controllability [54]. *Internal* attribution is when individuals identify that they themselves have caused an outcome. In contrast, *external* attribution will point to external factors as the causes. *Stability* explains whether or not the causes will be present in the future. For example, physical strength and crime rates are relatively stable, whereas effort and weather conditions are unstable. *Controllability* explains whether the causes of an outcome can be altered or modified. Within Attribution Theory, the way individuals attribute the outcome of events is associated with specific *emotional responses* [54], such as satisfaction and pride in reaction to positive outcomes [31]; as well as displeasure and guilt for negative outcomes [30]. Furthermore, individuals who attribute PA failures to causes that are *internal* (e.g., incompetence) and *stable* (e.g., it will happen again) can experience a decrease of success expectations and higher stress after a failure compared to those who attribute PA failures to external causes [28].

We found that PA trackers play a role in confirming caregivers' success in meeting their goals. As caregivers attributed their success to themselves, they also reported the feeling of pride and satisfaction, which encouraged them to challenge themselves. Inversely, confirmation that a PA goal was missed led to a feeling of guilt. Feelings of guilt have been briefly documented by prior work in PA monitoring tools [12,24]. Therefore, the design of PA tracking tools should maximize its positive role in confirming individuals' successes and at the same time reduce the intensity of negative emotions when depicting PA tracking data about missed goals. Moreover, low-SES families face higher crime risks, economic stresses, and reduced access to PA facilities [23]. As such, we underscore the importance of minimizing additional stressors, especially when designing PA trackers for low-SES populations.

In the context of children's experiences, attribution literature shows how adults' reactions to the outcome of a child's

behavior can influence the way the child perceives their competence [15]. For example, when adults give kids indiscriminate praise (i.e., one that does not align with the child's belief of the adult's expectation of them), such praise can be perceived as a cue of the child's incompetence because the praise was not seen to be attributed towards the child's ability [15]. Conversely, informative praise (i.e., one that is aligned with a child's belief of the adult's expectations) supports the child to attribute the success to their competence [36]. Given that adults' reaction to an outcome can unintentionally signal that their children are incompetent, we suggest that family PA trackers should help caregivers to communicate PA tracking outcomes in a way that supports their children's feelings of competence. Furthermore, given that individuals' attribution of PA outcomes can affect their emotional responses while using PA trackers, in the next section we will discuss how Attribution Theory can guide the design of caregivers and their children's interactions with PA trackers.

Emerging Processes During PA Self-tracking
Informed by our data, we will describe three processes that can support PA tracking in caregivers and children: *surprising discoveries*, *bodily experiences*, and *social mindfulness*. Guided by Attribution Theory, we will present design directions of how PA trackers can help families to *experience and celebrate progress*; by recognizing one's *internal* capacity, supporting the feeling of *control*, and highlighting that outcomes are part of a *stable* progress rather than temporal success or permanent failure.

Surprising Discoveries
Surprising discoveries are encounters with unexpected fitness data that challenge an existing perception. The idea of surprising discoveries in itself is not novel, as prior work has begun to document its emergence: Choe et al. described this as *contradiction* (i.e., "collected data contradicts existing knowledge") [6], whereas Baumer used the term *breakdown* [2]. We go beyond this prior work by unpacking the ways individuals experienced surprising discoveries.

Our data suggest that surprising discoveries gleaned from the PA trackers resulted in two processes: reflection on past experiences (e.g., P3, P10) and self-challenge (e.g., P5, P8). Reflecting on past activities seemed to help some caregivers identify activities that have better health benefits (e.g., bowling is a more active pastime than going to the movies). This is an essential step for individuals who may have understood the benefits of PA but who need actionable ideas for how to be more active [37]. Additionally, some caregivers challenged themselves upon learning that they surpassed their previously believed PA limits. These findings suggest that discovering unexpected positive outcomes that are attributed to oneself can impact self-efficacy. Self-efficacy—the belief that one has the capacity to successfully carry out a task—is crucial for PA adoption and maintenance [29]. We suggest that PA tracking tools should support caregivers and their children's self-efficacy by following up

surprising discoveries experiences with reflections. Such reflection should be designed to support an increased awareness of the progress that they have made.

Informed by Attribution Theory, we suggest that future work for family PA tracking should be designed to let caregivers *experience and celebrate progress* with their children. Therefore, rather than presenting PA tracking outcomes as goals that were achieved or missed, we suggest that future work should help caregivers and children be aware of the incremental progress they have made. For example, when a goal is met, PA trackers can help caregivers guide their children to learn that the surprising achievement of a goal was due to internal and stable progress (i.e., improved ability rather than luck). Similarly, when a goal is missed, PA trackers should empower caregivers to guide their children to reflect and be aware that they have made other important progress to improve their health (e.g., the family's initiative to start making a behavioral change; finding time and places to be active [37]). Such reflections on progress should be designed to promote self-efficacy and positive emotional responses by affirming families own role in their progress toward their health goals. Supporting positive emotional responses is particularly important for low-SES families who face increased stressors [23].

Bodily Experiences
Our data also suggest that surprising discoveries can co-occur with *bodily experiences*—in-body, felt sensations; when these processes co-occur, discoveries derived from PA tracking data can be triangulated with felt experiences. Our findings build upon those of Lomborg et al.*,* who described self-tracking is a way for individuals to communicate with themselves [26]. This communication extends one's bodily experience (e.g., moving one's body, fatigue) into a cognitive experience (e.g., learning how many calories were burned) [26]. In exertion games, Mueller et al. described bodily experiences as "awareness of exertion" [34].

For P3 and P8, these bodily feelings arose in the form of feeling tired and sweaty. For P5, the triangulation took place when he recalled his bodily movements that were summarized by the PA tracker in terms of step counts. Through this triangulation of body and data, participants were able to not only consider their PA cognitively, but also in a visceral way. These findings show how self-tracking tools can support more evocative data reflection [11].

In keeping with the theme of helping families to *experience and celebrate progress*, as users make progress towards their goals, PA trackers should invite them to experience *data visceralization* by helping them to reflect on and be attuned to positive *bodily experiences*. Data visceralization— "making data felt using various sensory and experiential techniques rather than only seen with the eyes"—can make data meaningful for lay users who may not be formally trained in data analysis [7]. Informed by Attribution Theory, data visceralization should support caregivers and children to attribute the positive bodily feelings to their increased

ability to be consistently active, perhaps using the PA data to confirm their progress. For example, PA trackers can prompt users to triangulate the tracker data with mindfulness of their breathing, the feeling of sweating, or their positive emotional reactions. Rather than using generic feedback that is unaligned with the family's interpretation of the outcome (provoking negative response such as incompetence) [15], triangulation can help families learn about their progress in a way that is more connected to how they perceive their experiences. Furthermore, prior work shows that families value the qualitative meaning of self-tracking data [38], suggesting that PA trackers should scaffold reflections on the meaning of bodily experiences.

Social Mindfulness
Our interviews also show how family PA tracking is supported by neighborhood social connections. We describe this phenomenon as *social mindfulness*—feelings of safety that come from an awareness that the community will look out for one another. As our interviews suggest, PA trackers may introduce uncomfortable feelings if being outside is perceived as a safety risk. Moreover, our participants described how prevalent crime is the norm and can affect anybody, suggesting that the risk is stable and uncontrollable. Experiencing multiple negative incidents that feel beyond one's control can lead to *learned helplessness*—a sense of powerlessness arising from repeated exposure to challenges [1] (e.g., people who come to believe that crime risks can affect them while outside at any time can feel less confident about being active outside).

Strategies to lessen learned helplessness include reducing the risk of negative outcomes and shifting the expectations so that the outcome feels more controllable [1]. Furthermore, individuals can acquire hopefulness when they experience outcomes that enhance their perceived control [56]. As our interviews show, caregivers suggested a sense of control when they described strategies to cope with crime risks, such as being mindful of their social environment. To further explain social mindfulness, we used Lofland's conceptualizations of realms—social spaces in physical places [25]. The caregivers described the realms where they feel comfortable because they have friends and relatives there. While crime is a real and complex threat, our interviews show that being mindful about safe social spaces can help caregivers to fine tune their perceptions of safety, by identifying places that are safer than others.

While, traditionally, social spaces have been conceptualized as a product of social interactions and cultural practices within physical places, Dourish suggests that technologies provide new ways for people to "understand and appreciate" physical places and offer alternative ways of constructing *social spaces* [10]. This place-space relationship is reflected in Humphreys' work examining users of Dodgeball (a location-based social networking app), who were involved in the production of social spaces in urban places [19]. Humphreys indicated that knowing through the app that a friend-of-a-friend is nearby, gave a feeling of familiarity and supported the production of parochial spaces [19]. Similar to P3's experience when she became acquainted with new individuals in a different part of her neighborhood, the notion of technology-facilitated social space productions also emerged in the study of families that played Pokémon GO, a location-based mobile game [47]. Families in that study described how the game gave them opportunities to connect and be social with other families. While families had some reservations about interacting with strangers, they were also surprised to learn how friendly 'stranger' families were.

Guided by this work, to help families *experience and celebrate progress*, we suggest that future PA trackers in low-SES contexts should support families to celebrate the identification of new places and social spaces that are deemed to be safe locales in which they feel comfortable being active. Furthermore, these discoveries should be established to help families experience a feeling of control over the crime barriers that their families may face.

Mapping features within PA trackers can help families identify safe places. We suggest that such features should go beyond crime mapping to instead map local resources that can heighten feelings of safety. Rather than disempowering caregivers by showing places where prevalent crime is uncontrollable; an alternative is to layer the map with places where families have friends or relatives who can help each other to feel safe. As evident in our data, caregivers perceive safety differently, depending on the type of social spaces that they are comfortable with. This finding underscores the importance of social maps that are unique and personalized to individual families. This design implication resonates with work on Reflective Informatics that suggests PA tools should invite families to identify social support—friends and relatives that can help them to be more active [41].

CONCLUSION
Wearable physical activity (PA) tracking use cannot be separated from the social connections and the emotional experiences that families have. Our qualitative study with families in low-socioeconomic status neighborhoods shows that the efficacy of PA trackers can be limited by caregivers' perceptions of crime. It was the depth of social contacts that caregivers had in their neighborhoods that helped empower them to be resilient in the face of disempowering narratives of crime. Furthermore, caregivers' explanations for their success or failure (as depicted by the PA trackers) were associated with emotional responses that could motivate or dissuade PA. Therefore, rather than presenting whether a goal was achieved or missed, we suggest that family PA trackers should guide caregivers and children to *experience and celebrate progress*.

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