In Situ Cues for ADHD Parenting Strategies Using Mobile Technology

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ABSTRACT

Parenting is always demanding, but families coping with neurodevelopmental disorders, such as ADHD, experience unique challenges. To address these challenges, research in the area of Parental Behavioral Therapy is accelerating. This type of therapy focuses on behavioral strategies that, if practiced regularly, can have a positive impact on the child's long-term behavior, as well as a reduction in parental stress. While these strategies are simple, there are hurdles to putting them into practice. First, parents often struggle with their own—often-undiagnosed—mental health challenges. Second, due to the needs of their children, parents are under immense stress in addition to regular, daily life stresses. Our work explores how to monitor parental stress and offers *in situ* support to remind parents of behavioral strategies to practice in moments of duress. We gained insight into how to design for the dynamics of families with ADHD children by using a prototype of our system as a probe. Our goal was to bring to the forefront simple strategies that can positively impact family ties and enhance the wellbeing of the child. We present results that suggest that when interventions are cued during moments of duress, technology might prove useful in supporting behavioral therapy.

Categories and Subject Descriptors

H.5.2 User Interfaces, H5.m Miscellaneous.

General Terms

Human Factors

Keywords

mental health, ADHD, just in time interventions, family, sensing

1. INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is a hyperkinetic psychiatric condition. It is one of the most diagnosed in school-age children with an estimated prevalence of up to 11% [6]. Children with ADHD experience challenges in maintaining attention, forming and holding goals, and cognitive control [3]. One of the most promising treatments to help children with ADHD is Parental Behavioral Therapy (PBT). PBT gives parents the skills to manage and teach their children behavioral strategies that focus on self-control. It is an approach that includes both parents and children as part of the behavior-change process.

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Figure 1. ParentGuardian's strategy delivery channels: mobile phone application (text and image) and glanceable display (image only)

Additionally, it reduces parental stress and increases parental confidence [32]. However, the barrier to its success is adherence, primarily for two reasons. First, ADHD is hereditary, which means parents could be struggling with ADHD themselves—most likely undiagnosed [11]. Second, parents of children with ADHD experience higher rates of anxiety, depression, and stress, which affect their ability to regularly practice PBT strategies [26].

There is an opportunity for technology to increase adherence to PBT. This work explores how to detect when parents are experiencing high levels of stress to provide contextually situated PBT strategies. To detect stress, we used Electrodermal Activity (EDA) as a proxy because changes in EDA represent physiological expressions of arousal. We focused on *in situ* support due to its potential to have long-term behavior-change benefits [20]. To understand familial needs and usage in real-world settings, we developed *ParentGuardian*, a working prototype deployed with 10 families over 14 days. This is the first study of *in situ* technological behavioral support for parents within the ecosystem around the child and not behavioral support for the child itself.

2. RELATED WORK

2.1 Health sensing technologies

A variety of mobile and/or sensor-based technologies have focused on encouraging and supporting healthy behaviors [7], [16]. In particular, in the mental health space, research has focused on collecting rich data with the goal of monitoring, recollection, self- and automatic assessment of valleys in mental health episodes [2], [19], [28]. These systems have focused on easing the process of self-monitoring by automatically detecting activity or behavior, with *in situ* feedback [28]. Our research explores detecting stressful situations in the home to deliver PBT strategies to parents in moments of needs. Offering *in situ* support in moments of needs allows us to explore the intersection of *in situ* support and *teachable moments* [20] for families as an ecosystem. Our goal is to help parents in stressful situations by presenting strategies in context that lead to long-term behavior-change in the child.

In addition to exploring the concept of teachable moments in the context of detecting stressful situations and provide coping strategies, our work is also grounded on Ecological Momentary Intervention (EMI), where a system should be able to assess and offer just-in-time prompting for behavior-change [25]. Mobile Heart Health and Mobilize! explored how to offer mental health support when an undesired mental state was detected [5], [23]. We contribute to this space in two ways. First, we explore how to offer *in situ* PBT support based on a physiological proxy for stress, using Electro-Dermal Activity data. Second, we examine a novel format for the delivery of such a strategy.

2.2 Leveraging electrodermal activity as a physiological indicator of stress

To detect stressful moments, we explored changes in EDA. Wearable EDA sensors detect changes in skin conductance. The sensor provides a sensitive and convenient way of measuring high physiological arousal associated with stress, as it can be worn conveniently on the wrist [27].

The work using EDA has mainly focused on controlled experiments, pattern recognition and understanding what representative features of different types of signal should be used by machine learning algorithms to automatically detect changes in arousal and therefore, mental state. The work by Hernandez et al. categorized different types of calls with respect to the stress level manifested by the call center staff with the goal of offering pertinent management techniques [14].

AffectAura explored how to monitor emotional wellbeing by visualizing emotional states and allowing users to reflect and understand what circumstances led to positive and negative affect. In this project, one of the sensors used as input to detect stress was EDA [22]. Similarly, FEEL, a work-in-progress system, explored correlating EDA readings with mobile-phone social interactions. The goal of FEEL is to offer insight between users' activities and their corresponding physiological responses [1]. We seek to push this concept forward by using EDA to identify stressful situations and offer support *in situ*. Additionally, we explore how PBT could help in the heat of the moment with parents and their children.

3. DESIGNING FOR ADHD FAMILY DYNAMICS

Designing for families with ADHD is particularly challenging, because parents need help the most when under duress. Consider the following scenario derived from our data:

Melissa and Peter are parents of two children, and both children are in the early grades of elementary school, one of them diagnosed with ADHD. The pressures of raising children coupled with the struggles of coping with ADHD have led to increased stress and depression for Melissa. By attending sessions with a behavioral therapist, both parents and children were taught strategies for self-control, self-awareness, and positive and effective communication. Melissa understands the benefits of practicing these strategies with her children; however, she struggles to remember and be mindful of them. It is especially difficult for her during her evening 'rush hour'—the time she is simultaneously helping her children with homework and extracurricular activities, preparing dinner, and staying on schedule that leads to bedtime. Add to the hectic evening, a child struggling to focus, loses patience quickly, and struggles to not fall off of the chair. Melissa struggles to implement these strategies regularly. This sense of failure increases her stress. She wishes there was a way to remind herself of these strategies in moments of need.

Addressing all the needs presented in this scenario is difficult. We therefore focused on exploring how to deliver PBT strategies when a high level of stress was detected from the parent. We developed *ParentGuardian,* a mobile/peripheral display application designed to intervene with illustrative suggestions upon stress detection. The following sections explain how we designed around the strategies and the components of *ParentGuardian*.

3.1 Designing the interventions

We chosen the intervention strategies to use based on collaborations with psychologists and behavioral therapists focusing on ADHD and PBT [18] (see Tables 1 and 2). Strategies fell into two categories: heat-of-the-moment and reflective. Heat-of-the-moment (Table 1) strategies suggest actions to take during moments of duress, such as, pausing before re-engaging in an argument with the child. Thus, we chose to trigger these when negative affect is detected in parents. The goal behind these strategies is to help parents become more mindful, resist negative emotional reaction, communicate effectively, and help teach self-control by example.

Table 1. Heat of the Moment Strategies

Heat of the moment strategies
Fill your lungs with air: Take three full, deep breaths
Silently count down from 5. Imagine each number changing colors.
Do you need a cool out? Disengage, walk away, take a 5 minute break.
You are your child's role mode. What do you want to teach?
Is my child pushing my buttons right now? How can I respond in a different way?
Stop, Look, and Listen.
Stay focused on the present, here and now, task at hand.
Choose self-control, over out of control.

Reflective strategies (Table 2) can be practiced at any time, and come in the form of reminders rather than actions. For instance, a reflective strategy might remind a parent to acknowledge the child's good behavior when the moment arises.

Illustrations are paired with the text of the strategy to create bidirectional associative links between 'seeing' and 'doing' over time [15]. Also, affect plays a role in learning and emotional response [17]. Therefore, after repeated reminders of the images linked to PBT strategies, it is possible to weaken the initial reaction and change the rebound effect such that parents, instead of reacting negatively, are mindful of the coping strategy to use [31].

Table 2. Reflective Strategies

Reflective Strategies (Categorized by themes)	
Modeling Behavior	Model what you want to see
	You are your child's role mode. What do you want to teach?
	When your child wants to show you something, show interest and ask questions. It means a lot to them.
	Give your child lots of physical affection -- children often like hugs, cuddles, and holding hands.
Planning For Consistent Behavior	Act, don't react.
	What is my plan for this situation? (What to do and say).
	Be consistent. Be predictable. Be prepared.
	Let your child know what the consequences will be if they misbehave.
	Have realistic expectations. All children misbehave.
	If you're upset, delay the consequences until you can act on it with full reason. This also gives your child time to reflect on the incident and what the consequence should be.
Acknowledgement of positive behavior	For every one bad thing you say, find 3 good points to highlight.
	It's okay to have strong negative feelings. It's what we DO with these feelings in the moment that matters.
	Accept that you are not perfect and will make mistakes. Allow yourself "redos."
	Think about one positive thing your child did today.
	None of us are perfect parents. Be kind to yourself.
	Give your child descriptive praise when they do something that you would like to see more often, e.g., "Thank you for doing what I asked straight away".
	Give yourself time to unwind, every week treat yourself to something you enjoy.

3.2 Designing in partnership with parents

Prior to the two-week deployment study, we met with parent participants to gain feedback on the strategies selected, their representations, and design ideas. During these sessions we discussed the combinations of the PBT intervention text and representative images sketched by a graphical designer. This approach ensured that the abstract, graphical representation matched the text and could be supported in both a mobile interface and a hands-free, peripheral display. We met with all ten parents individually, with each session lasting one hour.

During these discussions, parents noted a preference for the representation of the strategy without the text on the peripheral display. Therefore, we intentionally removed the text from the version for the peripheral display. The phone application's version however, contained both, as this was considered the primary delivery channel.

For privacy concerns, parents did not want audio or video recorded, even if it was just to detect features such as speech prosody for stress detection, not actual word recognition. Thus, we relied solely on the wearable EDA bracelet to detect stress. Parents were also debriefed on what data we would collect, how we would protect their privacy and by whom (the experimenters), and how the data would be analyzed.

Due to the limits of a four-hour battery life for the system, we could only explore a specific time of the day. Parents expressed there were two periods in the day that were high stress with their children: during the morning routine of getting their kids to school and the evening, which includes homework time, extracurricular activities, dinner, and bedtime. We chose the latter for our study as it gave us a larger window of time to explore interventions—6pm to 10 pm. In future work, we plan to explore other times of the day.

4. SYSTEM COMPONENTS

ParentGuardian is a four-part system: a mobile phone, a peripheral display, an Electro-Dermal Activity (EDA) wristband sensor, and a cloud service for back-end data analysis. The system was designed based on our goals and the needs expressed by our participants. Figure 2 shows a diagram of the system.

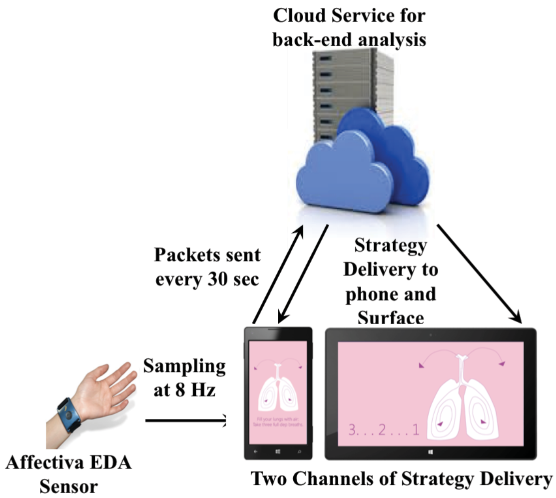

Figure 2. Components of ParentGuardian

4.1 Two channels of strategy Delivery

The EDA wearable sensing technology collects data but does not include a display. Therefore, we chose two channels to deliver PBT strategies: the mobile phone and a peripheral display. The following sections explain their functionality and purpose.

4.1.1 Mobile Phone Application

The mobile Microsoft Windows Phone 8 application allows parents to review strategies at any time and place. Through this delivery channel parents view both reflective and heat-of-the-moment strategies with accompanying text as often as desired (see Figure 3). First, the phone application prompts parents to report their emotions approximately every 1.5-2hrs – prompts can be ignored – and then to review both types of strategies. To avoid predictability of the strategies, the strategies presented after self-reporting appear in random order. Second, it connects to the EDA sensor via Bluetooth and streames data to a cloud service for analysis. Third, it delivers a heat-of- the moment strategy when a high level of negative arousal is detected.

Figure 3. Examples of strategies on phone: heat of the moment (left), reflective strategy (right)

We used the self-reports as ground truth for training our machine learning algorithms. In this version, there was no relationship between the self-report and which strategies appeared after self-reporting. In the future, we plan to explore leveraging self-reports to present pertinent PBT strategies.

The self-reporting tool used is based on Russell's Circumplex model, widely used across the affective computing community [22],[29]. The emotion is represented as two dimensions. The x-axis represents valence and the y-axis represents arousal. We used "Negative" to "Positive" to describe valence (x-axis) and "High Energy" to "Low Energy" to describe arousal (y-axis) as this was easier terminology for our users to understand.

4.1.2 Hands-Free Strategy Delivery

The peripheral display was built for Microsoft Surface RT tablet devices. The peripheral display is a direct response to parent reports of the need for a form of strategy delivery that could easily be viewed without having to look at their phones during the evening "rush hour". The idea was also grounded on the usefulness of glanceable displays and findings on the typical distance between users and their phone [10], [24].

To follow the model explained in Section 3.2, the peripheral display presents the associated strategy illustration without the text. During idle moments it acts as a live picture frame showing images of landscapes around the world. When stress is detected, it delivers the same heat-of-the-moment strategy as the phone (see Figure 4). The illustration appears for 20 minutes.

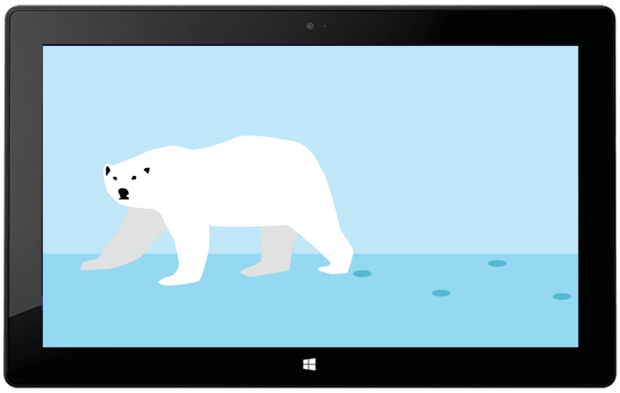

Figure 4. Strategy Illustration on the peripheral display

4.2 Sensing valence as a proxy for stress

The *Affectiva Q Sensor* (see Figure 2), which measures EDA along with accelerometer and body temperature[1], detects high states of arousal in parents using the ParentGuardian system. Data streamed from the sensor to the phone is then forwarded to a cloud service for analysis. The sampling rate was 8 Hz and features for machine learning were calculated on a 15-minute moving window. For each window, the system extracts multiple features: a count of data points, local min, max, mean, and the area of the signal's curve above the 75^{th}, 90^{th}, 95^{th}, 99^{th} percentile.

During this deployment, we used these features as input to an in house implementation of the Multiple Additive Regression Trees (MART) learning algorithm. MART is an efficient implementation of the gradient tree boosting method for predictive data mining (regression and classification) [12], [13]. The algorithm attempts to predict the state of valence (positive or negative) if the user were to self-report at that instant of time. In our current version, however, we cannot accurately predict the degree of valence, only if it is positive or negative.

Our MART algorithm was trained using EDA and self report data from a prior study with a different set of users [21]. We used 10-fold cross validation with the participant ID as a stratification key. When we first trained and tested this configuration, it resulted in a 91% accuracy rate. However, that accuracy was due to the participants from the previous study mainly self-reporting with positive valence (approximately 91% of the time), which resulted in the algorithm predicting positive valence every time. We tackled this weakness by balancing the data before using it to train. We balanced the data by stratifying the self-reports into 5 buckets based on the degree of valence they self-reported (x-axis of the 2x2 circumplex model). Taking the count of self-reports from the largest bucket we randomly duplicated self-reports in each of the smaller buckets until each bucket had the same number of self-reports. This process forced the learning algorithm to find other ways to detect negative valence and resulted in an accuracy rating of 78% using the 10-fold cross validation. We realize this is a weakness in our algorithm, so before we run another longitudinal study of ParentGuardian, we plan to collect and train on the parents' data to improve our detection.

[1] http://www.qsensortech.com/

Using the model explained above, if the algorithm predicted that the user would self-report as "negative valence" then our system sent an intervention to both the mobile phone application and the peripheral display. To prevent redundant interventions we restricted triggering interventions to only occur once every 20 minutes.

5. TWO-PHASE STUDY

The two-week deployment study was conducted in two phases, each lasting 7 days. During the first phase, parents used *ParentGuardian* without the sensor. This stage focused on self-reporting and familiarization with the tool. In the second phase, parents used the version of *ParentGuardian* with the wearable EDA sensor.

5.1 Participants

Ten parents participated in the study, 8 of them were mothers, with an average age of 38.4. For this study we focused on only one of the parents. All families were two-parent homes, with, on average, two children per household, all in the k-12 grades. To recruit the families, we used the ADHD assessment questionnaire [9]. Parents could complete the questionnaire for as many of their children as they desired. The questionnaires assessed the degree of ADHD behavior. The questionnaire included cut-off values by gender and age for what is considered ADHD behavior. We lowered the cutoff values slightly for the sake of the exploratory study. Participants were provided with three gratuities: one for the first brainstorming meeting, a second at the end of phase 1, and a third at the end of phase 2. Informed consent was collected.

5.2 Phase 1: Interventions without sensor

This phase allowed parents to familiarize themselves with the system and allowed researchers to gain insights on sending a coping strategy hourly instead of using EDA data to decide when to trigger an intervention. *ParentGuardian* consisted of the mobile phone and the peripheral display. They used the mobile phone to self-report and review both types of strategies during the day. The acts of self-reporting and gazing at intervention suggestions only took about a minute.

In the evenings, a heat-of-the-moment strategy was delivered simultaneously to the mobile application and peripheral display on an hourly basis from 6 pm to 10 pm. The order of the strategies was chosen at random to keep the content fresh and interesting (plus, one size never fits all).

At the start of week 1, we visited their homes for a tutorial on how to use the application and what to expect when a heat of the moment strategy was delivered to both the phone and the peripheral display. Parents were allowed to place the peripheral display at a location that was convenient for viewing. They chose location where they spend most of their evening hours, these were: the living room, kitchen, or family room.

5.3 Phase 2: Using EDA to detect stress

At the start of week 2, a home-interview took place to learn how our tool was supporting the behavioral strategies. We also updated the application and trained parents on how to wear the EDA sensor bracelet and to wear it between 6 pm and 10 pm.

In this phase, parents used the full version of *ParentGuardian*. Arousal data was collected from the EDA sensor worn by one of the parents. This data was streamlined and used by our machine learning algorithm to detect when to send an intervention. A heat-of-the-moment strategy was delivered simultaneously to the mobile application and the peripheral display based on detected need. Due to the novelty of the technology there were moments when signal was lost. Therefore, we sent one heat-of-the-moment strategy towards the end of the evening if no EDA readings were received throughout the entire evening, that way parents could experience at least one peripheral intervention. We randomly chose one of the nine interventions from Table 1.

Due to limited battery-life of both the phone and the sensor, the Bluetooth pairing had to be done manually by the user. If the sensor disconnected for more than 10 minutes between 6 and 10 pm, a notification would appear on the phone as well as on the peripheral display to remind parents to reconnect the phone with the EDA sensor. This was a major limitation in our study and is a problem for any wearable sensor today, but should be acknowledged. This did happen for some parents and it appeared in our logs.

At the end of week 2, a final interview took place to understand the feasibility and usefulness of triggering interventions based on detected arousal.

6. RESULTS

We collected multiple types of data to help us understand the effectiveness and usefulness of our system. We collected approximately 220 hours of EDA data, and 60 hours of data were lost due to technical failures. On average, our system delivered a coping strategy twice per evening.

Due to the complexity and novelty of *ParentGuardian*, parent participants sometimes encountered false-positive prompting or were not prompted during moments of duress with their children (false negatives). However, false positives tended to be reported as "obvious" to parents and easily dismissed. Nonetheless, when *ParentGuardian* triggered a true positive intervention, parents stated the *in situ* awareness was profound.

On average, parents self-reported 3 times per 4-hour session. Parents found the self-reports inconvenient. Conversely, they also stated that it reminded them to be mindful of their mood, something they would not ordinarily do before.

We collected qualitative data via structured interviews, log data around application use, and subjective data of users' opinions and beliefs about the prototype. Transcripts of the interview were analyzed using grounded theory techniques to allow for themes to arise bottom up. The interviews took place in the home and included some observations. The following sections discuss findings from both phases.

6.1 SUBJECTIVE RATINGS

Parents completed subjective questionnaires at the end of each phase (see Table 3). In general, parents rated the usefulness of the reminders to enter their mood, and the usefulness of the strategies and the display positively. Ratings at the end of phase 2 dropped, given that they had switched to automatic interventions based on EDA, but usefulness of the strategies was rated more positively in the second week. This is an interesting finding in itself as it suggests that contextual *in situ* support is more useful than hourly reminders.

With respect to the peripheral display, ratings of its usefulness went down the second week (see Table 3). Parents described their growing dissatisfaction as being related to the placement of the peripheral display, often not in the place most needed at the time of the intervention. Despite these challenges, the peripheral display did help parents recover from intervention cues missed on the phone. Thus, there is a need for more research on the best means for delivery of strategies in the context of the home.

At the end of phase 2, we also asked parents about the overall experience of using *ParentGuardian*. Using a scale of 1=not at all, 7=extremely), we asked them how effective the application was in helping them cope in the heat of the moment, and their response was positive (average=5.1). When asked how useful the strategies were, both in general and when presented in the heat of the moment, (both averages=5.1), they were equally positive.

Parents told us that they thought *ParentGuardian* was useful for learning coping strategies (average=5.1).

Table 3. ParentGuardian weekly subjective ratings

		Phase 1	Phase 2
Q1	How useful was the hourly reminder to enter your mood self-rating?	4.6	3.8
Q2	How useful were the strategies you went through after the self-report?	3.4	4.1
Q3	How easy was it to remember the intervention associated with an image when the displayed on the surface?	5.1	3.9
Q4	How easy was it to see the display in the room?	6.3	3.7
Q5	How useful was the display in reminding you of the strategies?	4	2.9
Q6	On a scale of 1-3 (1=once, 2=2-4, 3=5 or more times) how often did you visit the manually application daily?	1.3	0.8

There was no significance difference in self-report mood ratings between weeks 1 and 2.

7. INSIGHTS ABOUT AFFECT-CUED INTERVENTIONS

In the following sections we highlight insights gained from the study. These insights offer future design opportunities for situated cues for parental support within the family ecosystem.

7.1 Benefits of Situated Support

Despite the need to increase our accuracy on detecting stress, parents found the just-in-time interventions profound. The *in situ* cues made parents aware of their physical and mental state. This awareness helped them recover more swiftly from the situation than otherwise.

"I heard my phone "ding" and I was too busy to answer it but I knew what it was and I visualized some of the prompts, mostly the "modeling" one and I went about my business then Patricia who has little messes all over the kitchen was asked to clean up after herself [...] well in this process of her cleaning she somehow is creating more messes for me and in the past I usually snap at her out of frustration but...I didn't!!! I calmly explained how this makes more work for me and asked her to please focus on one mess at a time and get them cleaned up. It was so well received by her and I'm so proud of myself! Hopefully I can continue in this positive way." <PG4, mother of two>

Parents also discussed how these situated cues have the potential to help them identify their stress triggers with respect to their children. Additionally, they expressed the potential to help them trace back their steps to learn how to avoid getting into the same undesired situation of duress.

Like it made me aware of that I need to handle my stress differently. It made me aware of exactly which steps I'm taking to get me to be really stressed out, so it's like self-awareness. If you're stressed and you're screaming at people, you don't understand what's going on. You don't have time to understand what's going on, but if you're aware of the fact that you're stressed and first time it dings at you, you're like, "Oh, okay, I got it," and the next time, like a couple times, you're almost anticipating it to happen. Then you're controlling what you're doing up to that point, [...]" <PG6, mother of one >

These findings highlight the potential to further explore affect-based cues to delivery PBT strategies designed in conjunction with behavior-change concepts such as *Ecological Momentary Interventions* and *Teachable Moments* [20], [25]. Furthermore, unlike this study, health sensing has focused on applying the concepts mentioned above to design technology through the lenses of the individual in need. There is potential to explore how to design for these concepts from the perspective of indispensible stakeholders for behavior-change, in our case, the parents.

7.2 Trigger interventions earlier, during the escalation of stress

While real-time detection and prompting has the potential to improve adherence to PBT, the timing of the cue is crucial.

"It's not that you're stressed immediately, like you're super calm sit and drink your tea and then you're stressed the next second. It just builds up. Maybe a lot of people don't make a conscious effort and obviously, before I started paying attention to it, I wasn't making a conscious effort to control it. Maybe, if it's possible, to be able to tell you that you're getting there slightly earlier [...]" <PG6, mother of one>

Parents expressed that, when prompted before detecting a full escalation of stress, they were more receptive to the intervention strategy. Delivering a prompt at the peak of negative affect is potentially too late to recover.

"It was more like, when you're really tired and you're really grumpy, and somebody says, 'oh, somebody must be tired.' So, I'm all upset trying not to yell at my son, and my son's throwing a little hissy-fit [...] And my husband walks in and shoves the cool down app in front of my face, and I'm like, "[...], get that out of my face."" <PG8, mother of three>

Detecting escalating stress levels is a technical challenge to explore in future work, as it requires identifying features that identify a moderate increase in the physiological signals instead of features that represent peaks of negative affect. The dynamics of stress builds quickly over time, and then after a certain point, it is too late. It is key to intercede while the level is increasing.

7.3 Learning moments are different from training moments

Presenting strategies in detected moments of duress is not sufficient for learning and instilling the connection between moment of need and the strategy. Even though parents found situated interventions valuable, learning and reflecting on the strategies should occur in different moments.

"To be honest, when you are in the middle of that kind of rush hour in the evening when I'm trying to get homework done [...], I just don't have the time at that rush, in that little hour to keep scrolling through the pages and looking through them. <PG5, mother of three>

Because *ParentGuardian* proactively reminded parents to review these strategies regularly, parents used the *in situ* cue to quickly view the prompted coping strategy but focus on coming back to a calm state to tackle the task at hand with their children.

Once you start reading through them and once you get to the point where you've memorized them all, they are in the back of your head. It is kind of always with you, but there has to be that physical reminder or something that triggers it otherwise you might just forget. <PG3, mother of three>

7.4 Finding training moments

There are times when parents are more able to familiarize themselves with both types of strategies. For example, during idle times, such as in the early morning before the kids are awake, sitting during the child's extracurricular activities, or waiting in the car, parents in this study took advantage of the free moment to glance through instructional information.

"Because that's the time when your brain actually is free to think of other things. When you're racing against time during the evening stress hours, it didn't help as much. <PG5, mother of three>

Even though all parents considered the regular self-reporting mechanism to assess mood and review strategies a nuisance after two weeks, the system's regular reminders simulated the concept of detecting idle moments. Parents benefited from these reminders in two ways. First, they reminded parents to reflect and review the strategies when they received them during idle moments. Second, if the self-report prompt appeared before diving into a known stressful situation, it helped parents assess their mood and remind them of the toolbox of strategies at their disposal.

"Yeah, in the car, waiting for the kids to come out of school. I know that David is going to be hyper, and I know he's going to be on-edge, and I know there's going to be something negative that happened at school, because these are givens with him. So, having the thing pop up and say, "can I help you?" and me picking through them and saying, "OK, I'll take three deep breaths."" <PG8, mother of three>

Interestingly, our data shows parents did not open the mobile application on their own (i.e., without the prompt). There is an opportunity here to explore how to provide situated cues that remind parents to self-assess their mood and remind them of the strategies by expanding tools such as Place-Its or Dey's work [8], [30]. Exploring how to extend these tools in this manner could alleviate the nuisance of time-based self-assessment.

8. LIMITATIONS OF THE STUDY

There are four major limitations of this work. First, wearable EDA sensors are only capable of collecting and streaming data via Bluetooth. The sensors used in this study do not provide visual feedback about the state of pairing. Thus, we lost data intermittently as parents struggled to understand when the phone and the device were properly paired. Second, the sensor does not offer any form of user interaction. Therefore, we delivered the intervention through *ParentGuardian*'s mobile phone application and a peripheral display. In the future, we plan to explore the strengths and weaknesses around delivering strategies through an interface on the wearable sensing device itself and the two delivery channels we explored in this study. Third, after analyzing our data we learned our users tended to self-report with a higher rate of negative valence than the users we used to train our machine learning algorithm. Hence, parents reported that our detection algorithm missed negative affect moments that could have resulted in an intervention. In the future we need to train the algorithms with the actual users in order to personalize the intervention timing. Fourth, we have since learned how to better analyze EDA signals for stress detection. We plan to continue improving our detection methods in future work. That being said, we believe the system served as a legitimate probe to gain realistic insights on designing for the particular needs of parents under stress.

9. CONCLUSIONS

Parents are central to the education of their children, particularly when those children have significant behavioral challenges. However, due to the likelihood of parents living with neurodevelopmental disorders themselves and consequently elevated levels of stress, adhering to behavioral therapy strategies is difficult. Grounded on concepts from behavior-change and stress coping, this work focused on detecting high levels of stress in order to deliver parental behavioral therapy strategies.

This work demonstrates that *in situ* cues, such as those offered by ParentGuardian, can remind parents to implement these strategies during moments of need. However, the timing of the cue is crucial. Thus, systems to support parents coping with stress must detect peaks of negative valence as well as the escalation of a stressful situation.

Despite the demonstration of both feasibility and the potential for efficacy in this study, significant open questions remain. First, beyond *in situ* cues, there are other teachable moments in the day that can and should be leveraged. Future work should explore detecting idle moments for proactively prompting parents to reflect on and learn PBT strategies. Second, detecting negative valence based on EDA signals accurately still has a long way to go. Once the sensor suite and the algorithms are refined, a longer-term study is called for.

This work and the novel design of ParentGuardian focused on an unexplored component of the family ecosystem. We explored how to offer support to the parents in a way that benefits both the parents and the children. Additionally, this work provides a powerful case study for understanding how technology might support all of the members of a family, whose mental and physical health are intimately linked.

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11. REFERENCES

[1] Ayzenberg, Y., Hernandez Rivera, J., and Picard, R. 2012. FEEL: frequent EDA and event logging -- a mobile social interaction stress monitoring system. In *Proc. SIGCHI Conference in Human Factors in Computing Systems Extended Abstracts.* CHI EA '12, 2357-2362.

[2] Bardram, J.E., Frost, M., Szántó, K., Faurholt-Jepsen, M., Vinberg, M., and Kessing, L.V. 2013. Designing mobile health technology for bipolar disorder: a field trial of the monarca system. *Proc.SIGCHI Conference on Human Factors in Computing Systems.* CHI '13, 2627-2636.

[3] Barkley, R. A. 1997. Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological bulletin*, *121*(1), 65.

[4] Bauer, M., Grof, P., Rasgon, N., et al. 2006. Mood Charting and Technology: New Approach to Monitoring Patients with Mood Disorders. *Current Psychiatry Reviews,* 2(4), 423-429.

[5] Burns, Michelle Nicole, et al. 2011. "Harnessing context sensing to develop a mobile intervention for depression." *Journal of medical Internet research,* 13(3).

[6] Centers for Disease Control and Prevention. 2013 *National Survey of Children's Health.*

[7] Consolvo, S., Klasnja, P., McDonald, D.W., et al. 2008. Flowers or a robot army?: encouraging awareness & activity with personal, mobile displays. In *Proc. of the 10th international conference on Ubiquitous computing*. Ubicomp'08, 54–63.

[8] Dey, A.K. 2001. Understanding and Using Context. *Personal and Ubiquitous Computing 5*, 1 (2001), 4–7.

[9] DuPaul, G. J., et al. 1998. ADHD Rating Scale—IV: Checklists, norms, and clinical interpretation. Guilford Press, 1998.

[10] Fan, C., Forlizzi, J., and Dey, A.K. 2012. A spark of activity: exploring informative art as visualization of physical activity. In *Proc. of the 2012 ACM Conference on Ubiquitous Computing.* UbiComp '12, 81-84.

[11] Freitag CM. 2007. The genetics of autistic disorders and its clinical relevance: a review of the literature. *Molecular Psychiatry*, 12(1), 2–22.

[12] Friedman, J. H. 2001. Greedy function approximation: a gradient boosting machine. *Annals of Statistics*, 1189-1232.

[13] Friedman, J. H. 2002. Stochastic gradient boosting. *Computational Statistics & Data Analysis*, *38*(4), 367-378.

[14] Hernandez, Javier, Rob R. Morris, and Rosalind W. Picard. 2011. "Call center stress recognition with person-specific models." *Affective Computing and Intelligent Interaction*. Springer Berlin Heidelberg, 125-134.

[15] Heyes, C. M., & Ray, E. D. 2000. What is the significance of imitation in animals? *Advances in the Study of Behavior*, *29*, 215-245.

[16] Kay, M., Choe, E., Shepherd, J., and Greenstein, B. 2012. Lullaby: A Capture & Access System for Understanding the Sleep Environment. In *Proc. of the 2012 ACM Conference on Ubiquitous Computing.* Ubicomp'12, 226-234.

[17] Kensinger, E. A. 2004. Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences*, *15*(4), 241-252.

[18] Lakes, K., Vargas, D., Riggs, M., Schmidt, J., Baird, M. 2011. Parenting Intervention to Reduce Attention and Behavior Difficulties in Preschoolers: A CUIDAR Evaluation Study. *Journal of Child and Family Studies*, 20(5), 648-659.

[19] Lane, N., Mohammod, M., Lin, M., et al. 2011. BeWell: A Smartphone Application to Monitor, Model and Promote Wellbeing. In *Proceedings of the 5th International ICST Conference on Pervasive Computing Technologies for Healthcare*, 24-26.

[20] Lawson, P.J. and Flocke, S.A. 2009. Teachable moments for health behavior change: A concept analysis. *Patient Education and Counseling*, 76 (1), 25–30.

[21] Mark, G., Iqbal, S., Czerwinski, M., Johns, P. Capturing the mood: facebook and face-to-face encounters in the workplace. In *Proc. of the 17th ACM conference on Computer supported cooperative work & social computing*. CSCW'14, 1082-1094.

[22] McDuff, D., Karlson, A., Kapoor, A., Roseway, A., and Czerwinski, M. 2012. AffectAura. In *Proc. of the 2012 ACM annual conference on Human Factors in Computing Systems.* CHI '12, 849-858.

[23] Morris, M., Guilak, F. 2009. Mobile Heart Health: Project Highlight.*Pervasive Computing, IEEE,* 8(2): 57-61.

[24] Patel, S., Kientz, J., and Hayes, G., Abowd, G. 2006. Farther than you may think: An empirical investigation of the proximity of users to their mobile phones. In *Proceedings of the 8th international conference on Ubiquitous Computing.* UbiComp'06. Springer-Verlag, Berlin, Heidelberg, 123–140.

[25] Patrick, K., Intille, S. S., & Zabinski, M. F. 2005. An ecological framework for cancer communication: implications for research. *Journal of medical Internet research*, *7*(3).

[26] Plienis, A. J., Robbins, F. R., & Dunlap, G. 1988. Parent adjustment and family stress as factors in behavioral parent training for young autistic children. *Journal of the Multihandicapped Person*, *1*(1), 31-52.

[27] Poh, M.Z., Swenson, N.C., and Picard, R.W. 2010. A wearable sensor for unobtrusive, long-term assessment of electrodermal activity. *IEEE transactions on bio-medical engineering 57(* 5), 1243–52.

[28] Rabbi, M., Ali, S., Choudhury, T., and Berke, E. Passive and In-Situ assessment of mental and physical well-being using mobile sensors. In *Proc. of the 13th international conference on Ubiquitous computing.* UbiComp '11, ACM Press, 385-394.

[29] Russell, J. A. 1980. A circumplex model of affect. *Journal of Personality and Social Psychology,* 39(6), 1161–1178.

[30] Sohn, T., Li, K.A., Lee, G., and Smith, I. Place-its: A study of location-based reminders on mobile phones. *UbiComp'05 Proceedings of the 7th international conference on Ubiquitous Computing*, Springer (2005), 232–250.

[31] Solomon, R. L., & Corbit, J. D. 1978. An opponent-process theory of motivation. *The American Economic Review*, 12-24.

[32] Zwi M, Jones H, Thorgaard C, York A, Dennis JA. Parent training interventions for Attention Deficit Hyperactivity Disorder (ADHD) in children aged 5 to 18 years. *Cochrane Database of Systematic Reviews*. 2011.