Changing Family Practices with Assistive Technology: MOBERO Improves Morning and Bedtime Routines for Children with ADHD

Tobias Sonne[1], Jörg Müller[1], Paul Marshall[2], Carsten Obel[3], Kaj Grønbæk[1]

[1] Department of Computer Science, Aarhus University, Denmark

[2] UCL Interaction Center University College London, London, WC1E 6BT, UK

[3] Department of Public Health, Aarhus University, Denmark

{tsonne, joerg.mueller, kgronbak}@cs.au.dk, paul.marshall@ucl.ac.uk, co@au.dk

ABSTRACT

Families of children with Attention Deficit Hyperactivity Disorder (ADHD) often report morning and bedtime routines to be stressful and frustrating. Through a design process involving domain professionals and families we designed MOBERO, a smartphone-based system that assists families in establishing healthy morning and bedtime routines with the aim to assist the child in becoming independent and lowering the parents' frustration levels. In a two-week intervention with 13 children with ADHD and their families, MOBERO significantly improved children's independence and reduced parents' frustration levels. Additionally, use of MOBERO was associated with a 16.5% reduction in core ADHD symptoms and an 8.3% improvement in the child's sleep habits, both measured by standardized questionnaires. Our study highlights the potential of assistive technologies to change the everyday practices of families of children with ADHD.

Author Keywords

Children; attention deficit hyperactivity disorder; ADHD; sleep; mobile; assistive technology; mental health; routines; behavior change.

ACM Classification Keywords

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

INTRODUCTION

In recent years, HCI researchers have demonstrated the potentials of using interactive technologies to assist people with various deficits and disorders [4,25,43]. However, only few examples of research within the HCI community have been reported on assistive technologies for the Attention Deficit Hyperactivity Disorder (ADHD) domain (although see [34,40,48]). ADHD is the most prevalent mental health diagnosis among children aged 3–17 [49] with a worldwide prevalence of approximately 5% among children and adolescents [35]. As a consequence of the difficulties caused by the ADHD disorder, such as inattention, hyperactivity, impulsivity and behavior problems, there is a significant burden on those affected, their families and society [20]. Traditional ADHD treatments include prescribed medication [21], cognitive training [28] and parent training [1].

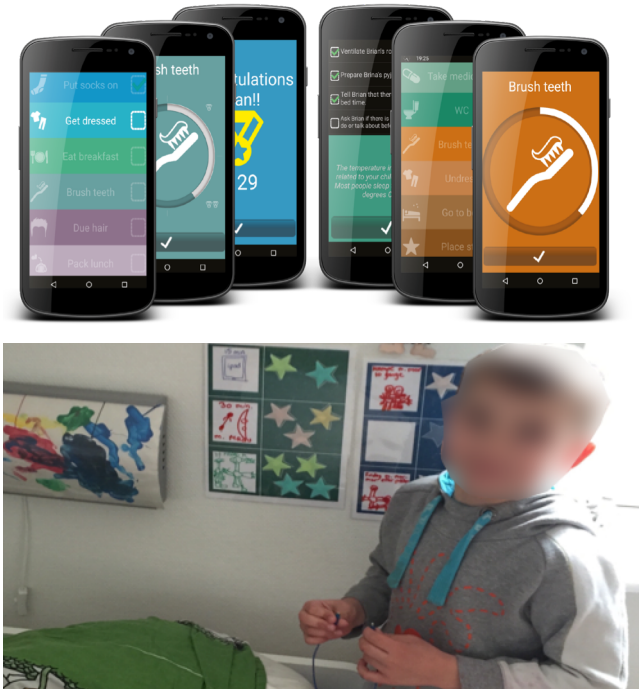

Figure 1: Top: MOBERO. Bottom: A child explaining and showing his rewards collected from using MOBERO in a two-week study (Permission to use photo granted by parents).

In this paper, we present a supplementary technology-based approach to support families of children with ADHD. Our aim is to assist the family in establishing effective morning and bedtime routines, as these situations can be particularly stressful and frustrating for parents of children with ADHD [14,18,36,46]. Furthermore, an effective bedtime routine is important, as sleep deprivation affects the child's executive

CHI'16, May 07-12, 2016, San Jose, CA, USA
 ISBN 978-1-4503-3362-7/16/05...$15.00 DOI: http://dx.doi.org/10.1145/2858036.2858157

functions and manifests in more hyperactivity and inattention, poorer concentration, disruptive behaviors and poor school performance [14,16]. Through a design process involving parents of children with ADHD and ADHD domain professionals consisting of two child psychiatrists, three psychologists, and three medical researchers we developed a Morning and Bedtime Routines smartphone system (MOBERO – see Figure 1) in order to investigate our hypotheses that mobile technologies can lower the parents' frustration level during their child's: 1. morning; and 2. bedtime routines; assist the child to become more independent during 3. morning and 4. bedtime routines; and 5. improve the child's sleep habits. We report on a four-week study of MOBERO with 13 children with ADHD and their families. Quantitative results showed that MOBERO was associated with a significant increase in the parents' rating of their child's independence level, a decrease in parental frustration during the child's morning and bedtime routines and more consistency in the times the child went to bed. In addition, we discovered a significant improvement in both parent-rated ADHD symptoms and the child's sleep habits. Qualitative data from interviews with the families support our quantitative findings, and further provide insights into their use and experience of MOBERO, including some unexpected negative effects related to rewards and tailoring.

BACKGROUND AND RELATED WORK

To understand the ADHD domain, we provide a background to the ADHD diagnosis, the challenges families with ADHD experience and the effects of unhealthy sleep habits. We then position our work within related work on assistive technologies to support habits and routines.

Attention Deficit Hyperactivity Disorder (ADHD)

ADHD is childhood-onset neurodevelopmental disorder with a worldwide prevalence of approximately 5% among children and adolescents [35]. In addition to the behavioral challenges mentioned above, ADHD is associated with impaired academic performance [19,31], difficulties in interacting with parents and teachers [42], increased risk of criminal convictions in adulthood [15,30] as well as increased mortality [3]. Furthermore, it has been shown to significantly affect children's quality of life [45]: for example in one study 70% of third graders with ADHD reported that they have no close friends [45].

ADHD is a controversial diagnosis, although most researchers argue that it is valid [6]. Rather than taking a side in this debate, we designed MOBERO to provide support for specific challenges associated with the disorder.

Routines and Frustrations in Families with ADHD

Studies have found that parents of children with ADHD find morning and bedtime routines especially challenging and stressful [18,36]. This is also supported by additional studies, showing that children with ADHD exhibit more bedtime resistance than those without (see [14] for a review). Furthermore, studies of parental coping strategies have found that techniques such as structure, routines and rewards are effective in assisting the child during morning routines [18]. Many of the challenges these families experience are compounded by ADHD, as some of the effects of the disorder include challenges in/with: handling transitions between activities; low self esteem; perceiving time; remembering a sequence of instructions; sustained attention; disruptive behavior; and lack of motivation [20]. In addition, ADHD is often seen to co-exist with other disorders (e.g. conduct disorder), which can cause additional deficits and challenges.

The Importance of Adequate Sleep for Children

Adequate sleep is especially important for the developing child [16], as insufficient sleep and poor sleep quality negatively impact school performance [16]. Sleep is central in ADHD, as the disorder is often linked to abnormal sleep. Children with ADHD may have difficulties in getting to bed and falling asleep and may have irregular sleep patterns. These challenges tend to worsen problems with hyperactivity, inattention, difficulty in concentrating, disruptive behaviors, and poor school performance [14]. Consistent bedtimes have shown to improve sleep [8]; however as children with ADHD exhibit bedtime resistance, set bedtimes can be difficult to implement.

Technologies that Support Habits and Routines

A number of HCI researchers have explored opportunities to use technology to support healthy sleep routines (see [9] for an overview). An example is 'Lullaby', which tracks sleep and environmental parameters like temperature and noise level, supporting adult users in creating optimal sleep conditions [24]. Another example is 'ShutEye', which attracts attention to activities (e.g. drinking coffee) that might improve or worsen sleep via an ambient representation on the user's mobile phone [5]. The most recent example is 'SleepTight' [10], a mobile-phone based system that investigates how to lower the burden of manually tracking sleep, as automatic tracking of sleep reduces the user's engagement and awareness, which are critical elements for behavior change.

In contrast to technologies to support sleep for healthy adults, there has been very limited research on assistive technologies for the ADHD domain. 'ParentGuardian' is a system that delivers in situ parental behavioral therapy cues to parents of children with ADHD in situations of stress [34]. High stress levels are detected through a wrist worn device, triggering reminders on mobile phones and a glanceable display of coping strategies. Another example of a system that provides real-time feedback is 'CASTT' [40], which is designed to support children with ADHD in sustaining attention in the classroom. The system most related to our research is 'TangiPlan', a tangible interface designed to improve executive functioning for children with ADHD during their morning routines [46,48]. TangiPlan consists of multiple tangible objects each representing a task (e.g. get dressed) and through an array of LED lights,

the child is informed about the remaining time to complete the task. A paper prototype of TangiPlan was evaluated with three users [46] and later a 3D printed model was evaluated with two users [48] with positive feedback. However, TangiPlan, CASTT and ParentGuardian are all designed for the individual and not the family. Slovák et al. [37] highlight the importance of including parents when designing technologies to support social and emotional skills training for children. An example from outside the ADHD domain that does involve parents in supporting the child is TalkBetter, which provide in situ cues to the parents of children with language delay [22]. TalkBetter consists of two mobile phones, one for the child and one for the parents, and based on analysis of the conversation, it triggers auditory feedback to the parents like "*Please talk more slowly*" and "*Please do not interrupt your child*" [22].

Several technologies that try to establish or change behavior have been studied like Fish'n'Steps [29] and UbiFit Garden [11,13], which both encourage people to be more active. Even though most behavior change applications are designed for adults, some have been designed specifically for children [2,26]. However, Stawarz et al. criticize many existing behavior change applications (both commercial and within HCI research) for not being theoretically grounded in habit formation theory [41], limiting their ability to support long term change.

We introduce a novel approach as the first to focus on bedtime routines for children with ADHD by building upon existing research on adult sleep technologies, and focus on how technologies might improve the sleep of children. Furthermore, we contribute to the very limited work on assistive technologies for ADHD by designing for the family instead of only the individual. Finally, we expand existing work on behavior change technologies by developing to support the whole family in order to support the child in changing their daily practices.

DESIGNING WITH PARENTS AND PROFESSIONALS

In this section we present our design process and describe how ADHD professionals and families influenced the design of the MOBERO system and the user study. Our design process included two pilot studies with two families with children with ADHD and ADHD professionals (three psychologists, two child psychiatrists and three medical doctors and researchers from the ADHD domain). The two families were recruited through the Center for ADHD, Aarhus, Denmark, which offers parent-training programs for parents of children with ADHD. The initial concept and prototype of MOBERO were established through meetings and workshops with the ADHD professionals and was designed to be playful, lightweight and to provide structure for families of children with ADHD in providing support for bedtime routines only. The first family evaluated the prototype for four weeks and then the second family used it for three weeks. The parents were encouraged to contact us during the evaluation if they had suggestions for improvement or general feedback. After each pilot study, we conducted a one-hour semi structured interview with the family addressing their experiences with MOBERO. The feedback from the first family was incorporated into the version of MOBERO tested with the second family, and in collaboration with the ADHD professionals we agreed on changes that ended up constituting MOBERO. Below, we highlight findings from our design process that changed our initial concept and prototype.

Designing for the Family instead of the Individual

Our initial goal was to improve the sleep quality for children with ADHD though the use of technology, as poor sleep negatively affects the child [14,16]. However, in contrast to existing technologies focusing on changing sleep habits for adults (e.g. [5,10,24]), we learned from the ADHD professionals that we should not design for the individual child because of the importance of family dynamics in establishing routines. However, as ADHD is highly heritable [6,45], the parents might themselves have challenges in providing the structure needed to create a consistent bedtime routine. Therefore, we ended up designing MOBERO for the whole family by including routines for both parents and children.

Identifying the need for Additional Support Modules

One week into the first pilot study the family contacted us and asked if we could extend MOBERO to include morning routines too, as they also had challenges getting their child ready for school in the morning. As frustrating mornings both affect children and parents, we decided to expand the functionality of MOBERO by integrating a morning module into the system. Furthermore, we had planned to use a paper based sleep diary (which child psychiatrists normally ask parents to complete as part of the ADHD investigation) to evaluate MOBERO's impact on the child's sleep quality. However, the pilot studies taught us that the families often forget to complete the sleep diary (cf. [10]). To encourage engagement in the evaluation, we developed the Daily Assessment Application (DAA) as a digital version of the sleep dairy with a built in notification system that would remind the parent to report data daily. The DAA also allowed us to assess the accuracy of the reported data, as we logged when the parents made entries in the app.

Creating Valuable Rewards

Both parents and ADHD professionals emphasized that rewards are an effective motivator for children with ADHD, a claim supported by both the HCI and ADHD literature (cf. [11,32]). In order to explore the effects of different kinds of rewards, we incorporated two kinds into MOBERO: virtual medals for completing morning routines in predetermined durations and a physical fluorescent star for completing all bedtime routines (see Figure 1), that the child could place on a laminated reward sheet. The reason for choosing a physical reward was two-fold. First, as many children with ADHD often have developed low self-esteem [20], one of the ADHD professionals explained that a physical acknowledgment could work as a manifestation of

the child's achievement and success, that would be visible to themselves and their family and friends. Second, the fluorescent stars were part of another reward. The placeholders for the fluorescent stars were in three groups on the A4 rewards sheet, and for each group there was a space where the child could draw the reward that this group of stars should unlock (see Figure 1). Originally, we intended to provide the family with small presents like e.g. LEGO Mini Figures. However, one of the ADHD professionals suggested that the reward should be used for family activities like playing a game or building LEGO together. Therefore, the families were encouraged to choose rewards that involved parent-child activities inspired by the Incredible Years parent training program [44] used at the Center for ADHD, Aarhus, Denmark. Child-directed play draws from social learning theory and provides a foundation for building positive child-adult relationships and strengthening the ties between child and parents [44].

THE MOBERO SYSTEM

MOBERO was installed on a LG Nexus4 Android-smartphone that was provided to the families during the study. Both MOBERO modules (morning and bedtime) were developed to assist the child in becoming more independent in daily routines and to reduce the parent frustration level. We attempted to achieve this by establishing and supporting routines for both the child and the parents.

MOBERO Bedtime Routines

The MOBERO bedtime module includes activities for both the child and parents to complete (see Figure 2):

1. 15 minutes before the set bedtime, MOBERO notifies the parents to begin their bedtime routines for the child. The auditory notification keeps ringing until the parents either snooze it or start their activities. Having pressed the start button, the parents see a short list of activities for them to complete in order to prepare for their child's sleep, e.g. ventilate their child's bedroom.
2. When the parents have completed their activities, a countdown view displays the remaining time until the child should initiate her bedtime routine.
3. A visual list representation with both pictograms and text provides an overview of the activities that make up the child's bedtime routine. A dedicated view for an activity is shown when it is selected.
4. The last activity in the MOBERO bedtime module is a reward in the form of a physical luminous star, which the child can place on a laminated A4 rewards sheet.

MOBERO Morning Routines

The MOBERO morning module is designed to assist children with ADHD to complete their morning routines from when they wake up until they leave home for school. The module contains three general views (see Figure 3):

1. A visual list representation of the morning routines;
2. A view for each activity with a textual description of the routine, a pictogram representing the routine, a circular visual timer indicating the time elapsed/remaining that is connected to a representation of the expected reward (numbers of medals)
3. A final view showing the total number of collected medals during the morning routines.

In both the MOBERO bedtime and morning modules the order of the routines cannot be changed by the child, thus they have to complete them in the order that is shown. However, the routines might not be identical from one day to another, as the child might have different routines on certain days (e.g. remember gym clothes every Thursday). The specific routines were chosen by the parents as they know their child's routines the best, but most included the same "backbone" routines e.g. put socks on, get dressed, eat breakfast, brush teeth, pack backpack and put jacket, shoes, and bike helmet on.

Having presented the two MOBERO modules we now introduce our study.

THE MOBERO USER STUDY

We conducted a four-week study with 11 families and 13 children with ADHD in order to investigate our hypotheses that MOBERO could lower the parents' frustration level during their child's: 1. morning; and 2. bedtime routines; assist the child to become more independent during 3.

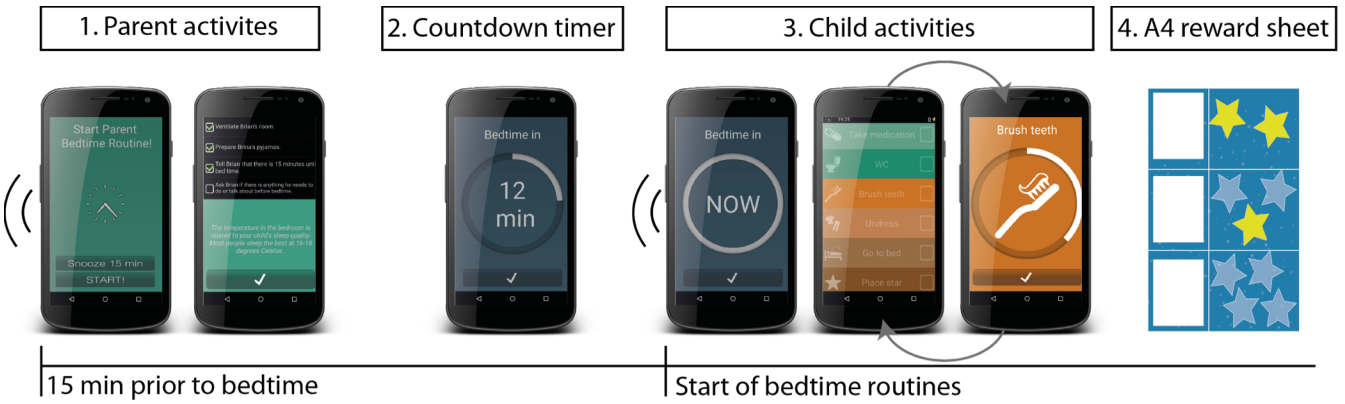

Figure 2. The flow of the MOBERO bedtime module including the child's physical rewards sheet. (The original text was in Danish).

morning and 4. bedtime routines; and 5. improve the child's sleep habits. We were also interested to see if MOBERO had an effect on the parent-reported ADHD symptoms as well as the child's sleep habits, both evaluated though the use of standardized questionnaires. Furthermore, we wanted to investigate the qualities and challenges that families with children with ADHD experienced using MOBERO to establish healthy morning and bedtime routines.

Prior to beginning the study, ethical clearance was granted by the regional ethical committee. The families did not receive any payment for participating in the study.

Study Design

Overview of Dependent Variables

Table 1 provides an overview of the collected data.

Data collection	Collected information
DAA	Child bedtime, sleep time, wakeup time and parent assessment of frustration and child independence.
ADHD-RS	Child ADHD symptoms.
CSHQ	Child Sleep Habits.
Screening questionnaire	Parent assessment of frustration and conflicts, and insights into family routines.

Table 1. An overview of the data collected as part of our four-week MOBERO study.

Questionnaire Measures

The Daily Assessment Application (DAA)

The purpose of the DAA was to collect daily parent assessments. Therefore, the DAA notified the parent once a day to report: 1. the child's wake-up time; 2. their bedtime; 3. their sleep time; the parent's rating of the child's independence during 4. morning- and 5. bedtime routines; and their own frustration level during the child's 6. morning and 7. bedtime routines. Questions were all reported through a five-item Likert scale (strongly disagree - strongly agree). Furthermore, DAA included an option for parents to write comments they found relevant to report.

ADHD Rating Scale-IV (ADHD-RS)

ADHD-RS is a validated tool used in ADHD diagnosis to measure the severity of symptoms and to evaluate the treatment efficacy in children and adolescents with ADHD [17]. As ADHD in Denmark is diagnosed accordingly to the International Classification of Diseases 10 (ICD-10) as a Hyperkinetic conduct disorder [47], we use the version of the ADHD-RS modified to match the ICD-10 diagnostic criteria. Thus, the version of ADHD-RS used in our study contained a total of 26 questions, with 18 covering the core diagnostic ADHD symptoms of inattention, hyperactivity and impulsivity in addition to eight questions covering symptoms of conduct disorder, which is the most common comorbidity with ADHD. We used ADHD-RS to select

Figure 3. The MOBERO morning module. 1: The list of the morning activities. 2: A specific routine with visualization of time and rewards. 3: The final reward screen.

families for our study and to evaluate the treatment efficacy of MOBERO on the children's ADHD symptoms.

Children's Sleep Habit Questionnaire (CSHQ)

The CSHQ is a validated parent reported sleep screening survey specifically designed for school-aged children [33], which consist of 35 questions conceptually grouped into eight subscales: 'bedtime resistance', 'sleep onset delay', 'sleep duration', 'sleep anxiety', 'night wakings', 'parasomnias', 'sleep-disordered breathing' and 'daytime sleepiness'. We used the CSHQ to evaluate the treatment efficacy of MOBERO on the child's sleep habits and sleep quality, by comparing CSHQ before and after our study.

Participants

The participating families were recruited through the Center for ADHD (eight), through a child psychiatrist (six), and by word of mouth (two). A total of 16 families signed up for participation, but only 11 families were selected to participate based on our inclusion criteria, which were: 1. the families should reply 'often (two to four times a week)' to a least two statements in a screening questionnaire on how often they experienced conflicts/ frustration around their child's morning/bedtime routines; and 2. The child should be clinically diagnosed with ADHD or under investigation for ADHD and have an ADHD-RS score within the ADHD range [47]; 3. Children should not be below the age of six; and 4. Children should not have a condition other than ADHD as the primary diagnosis.

Of the 11 families included, two had two children who both met the inclusion criteria. Thus, a total of 13 children participated in the study. The 13 children (four female) were aged between six and 12 (average age = 9.3). The mean parent-rated ADHD-RS score was 39.18 (inattention and hyperactivity/impulsivity) and 11.69 (behavior). All individual ADHD-RS scores were in the range expected from gender and age stratified normative data scores for children clinically diagnosed with ADHD [50]. Seven children received medication as part of their ADHD treatment; however, no changes were made to the medication dosage during the MOBERO study. Furthermore, as none of the children had recently started on medication or had made changes to their medication, the

effect of medication should not impact the findings in our four-week study. On the contrary, for the children receiving medication the effect of MOBERO might be lower due to its effect on core ADHD symptoms.

Procedure

The user study was divided into a two-week baseline phase and a two-week intervention phase. Prior to the baseline phase, families completed the ADHD-RS and CSHQ questionnaires. All families were asked to participate for two weeks in each phase, however due to variance in scheduling visits, most families experienced the phases as longer than two-weeks.

MOBERO baseline period

On the first day of the baseline phase, we visited the families and conducted a short interview about their experiences with their child's ADHD diagnosis. They were then introduced to the study design and the parents were instructed in the use of the DAA, and encouraged to use it every day during the baseline and intervention phases. Halfway through the baseline period, the parents were contacted by email and asked to list the specific morning and bedtime routines they would like to have in their version of the MOBERO system.

MOBERO intervention period

After the approximately two-week baseline phase, we returned to the families and introduced them to MOBERO. The families were then encouraged to incorporate MOBERO into their daily morning and bedtime routines for the remaining two weeks of the study. We furthermore informed the parents that we could update MOBERO over-the-air, and emphasized that they should not hesitate to contact us if they wanted to make changes to their routines.

After the intervention phase, we visited the families to conduct an approximately one-hour semi-structured interview about their experiences with MOBERO. Additionally, the parents were asked to complete the online ADHD-RS and CSHQ questionnaires.

Data Analysis

Parent rated frustration levels and child independence processing

As we did not assume the same number of DAA entries between families, we took the median values for for each child for the parent rated frustration levels and child independence for both the baseline and intervention periods. so that all children accounted equally in each category. Measures for the baseline and intervention periods were compared with two-tailed Wilcoxon Signed Rank tests.

Parent rated bedtime and sleep time processing

From the parent reported bedtime, sleep time, and wakeup time we calculated the child's sleep delay and the total sleep time, where sleep time refers to the time the child fell asleep and sleep delay refers to the duration between bedtime and sleep time. As we did not assume the same number of entries between families, we took the mean value for each question for each child so that all children account equally in each category. Measures for the baseline and intervention periods were compared with two-tailed paired t-tests.

Questionnaire Processing

We used a two-tailed paired t-test on the ADHD-RS scores to evaluate the treatment efficacy of MOBERO on the child's ADHD symptoms. Similarly, a two-tailed paired t-test was used to evaluate the efficacy of MOBERO on the CSHQ.

Interview processing

The audio-recorded interviews were recorded, transcribed and analyzed in Danish and thematically analyzed [7]. Selected sentences were translated into English for presentation. Names were changed and personal information was removed to preserve anonymity.

RESULTS

Higher Child Independence from Using MOBERO

There was a significant improvement in responses to the daily parent-reported answer to the question "*[The child's name] was independent during the morning routines?"* between the baseline (Mdn = 3: *neutral*) and intervention (Mdn = 4: *agree*) phases, $z = -2.28$, $p<.05$, $r = 0.45$. Similarly, the response to *"[The child's name] was independent during the bedtime routines*?" improved between the baseline (Mdn = 3: *neutral)* and the intervention phases (Mdn = 4: *agree*), $z = -2.02$, $p<.05$, $r = 0.40$ as seen in Figure 4. Our qualitative analysis supports the quantitative findings as exemplified by Simon's mother "*Before we started this, we should almost be giving him shoes on every day -'Who will help me?' It has not at all been like that - he has just done it. Even putting his lunchbox in his bag he has just done it.*"

Parents Report Lower Frustration During Their Child's Morning and Bedtime Routines

Parents' reported frustration level during the morning routines reduced between the baseline (Mdn = 3: *Neutral)* and the intervention (Mdn = 2: *Disagree)* phases, $z = 2.76$, $p<.01$, $r = 0.54$. Similarly, parent reported frustration levels around the child's bedtime reduced between the baseline (Mdn = 3: *Neutral*) and intervention (Mdn = 2: Disagree) phases, $z = 2.52$, $p<.05$, $r = 0.49$. This is supported by our qualitative findings as we see a similar pattern exemplified by comparing how Brian's parents described their bedtime routines prior to the study "*There is a yelling and screaming from all sides, even from ours, up until the last half hour before he [Brian] sleeps or is in his bed [...]. (Interviewer) How does this make you feel? (Mother) Super frustrated. We have of course often been very sorry when putting him to bed, and mad, and frustrated and yes. (Father) When you first come downstairs, you simply just collapse. (Mother) There have been times when I almost did not have the strength to put him to bed [...]*", to how they described it when using MOBERO "*[...] we've got calmer*

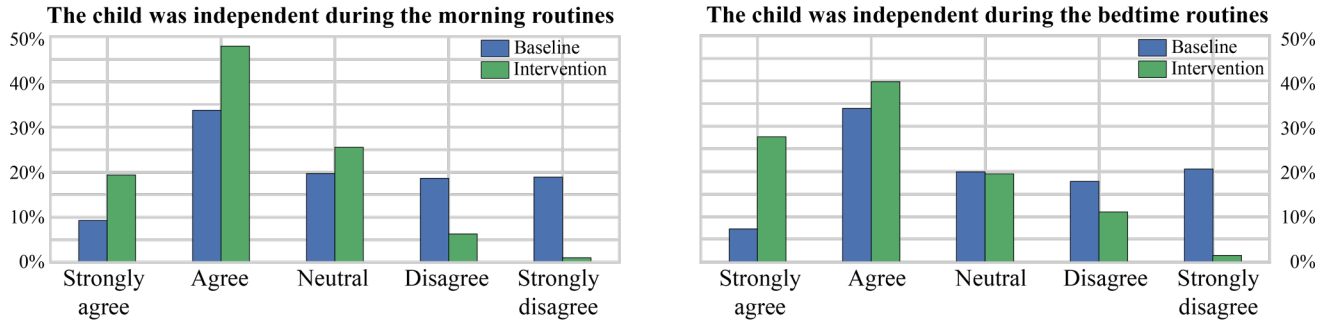

Figure 4. The distribution of daily parent responses to questions about their child's level of independence during morning (left) and bedtime (right) routines.

and better evenings, and it has been pleasant to tuck him in. There have been more loving and quiet moments than conflict, and it's really nice". Another example is from Søren's mother "*It has often been a struggle [to get the child to wash his hands]. But now, well it is on the phone, so now it is no problem (laughing)"*.

Improvements in the Parent Rated ADHD symptoms

We observed a 16.5% drop in the traditional ADHD-RS score (i.e. 'inattention', 'hyperactivity' and 'impulsivity') between baseline (M=39.4, SD=5.4) and intervention (M= 32.9, SD=5.5) periods, t(12) = 2.59, p<.05, Cohen's *d*=0.73, suggesting that using MOBERO was associated with an improvement in the children's ADHD symptoms.

Looking at the ADHD-RS subcategories separately, there was a 20.1% reduction in the inattention score between baseline (M=21.46, SD=4.67) and intervention (M=17.15, SD=4.81), t(12) = 2.63, p<.05 Cohen's *d*=0.73, suggesting that MOBERO was associated with an improvement in children's ability to attend to tasks. In the hyperactivity/impulsivity subcategory, there was a 12% reduction between baseline (M=17.92, σ=5.72) and intervention (M=15.77, SD=6.19). However, this difference was not significant t(12) = 2.63, p>.05, Cohen's *d*=0.57, suggesting that MOBERO was not associated with improvements in the children's hyperactivity / impulsivity.

As our version of ADHD-RS included eight additional questions related to conduct disorder, we additionally identified a 26.3% reduction in the 'behavior' score between baseline (M=11,96, SD=5.34) and intervention (M=8.61, SD=6.04), t(12) = 3.68, p<.01, Cohen's *d*=1.02, suggesting that MOBERO was associated with an improvement in children's behavior.

MOBERO Improves the Child's Sleep Habits

Comparing the CSHQ scores before and after the MOBERO study, we see an significant improvement (8.3%) from a mean CSHQ score of 58.62 (SD=10.87) to 53.77 (SD=8.27), t(12) = 2.43, p<.05, Cohen's *d*=0.67. Furthermore, we see a positive change in seven of the eight CSHQ subscales: 'bedtime resistance', 'sleep duration', 'sleep anxiety', 'night wakings', 'parasomnias', 'sleep-disordered breathing' and 'daytime sleepiness'. However, we saw no improvement for the 'Sleep Onset Delay' subscale. This is consistent with the parents' descriptions of their child's ability to fall asleep during the intervention phase "*Well, he still has difficulties falling asleep*" (Michael's dad) and "*It is not because he falls asleep earlier*" (Simon's mother). Interestingly, six families improved the CSHQ score related to the child's need to move to another bed (e.g. the parents') during the night, which is also exemplified by Ryan's father *"[...] before, [Ryan] stayed in his own bed once a week, now I experience it as it is almost diametrically opposed, now it's once a week he comes down to us – at most.*"

Positive Effects on Bedtime Consistency

Though we see a positive tendency in bedtime consistency (see Figure 5), we did not find a statistically significant change in bedtimes between baseline and intervention phases, t(10)=1.9, p=.08. Furthermore, we did not find significant changes between the baseline and intervention for sleep time t(10)=1.5, p>.05 or sleep delay t(10)=0.3, p>.05 which are consistent with our analysis of the CSHQ.

Visualizing Time can be a Double Edged Sword

Most parents emphasized that the visualization of time in MOBERO (see Figure 2 and Figure 3) was very useful for the children as it kept them on track during the morning and bedtime routines: e.g., "*It has become easier for him to see it [time]. Before I used the hands of a clock to show him, now it is just so much more clear to him"* (Simon's mother) and "*The fact that he can see the time passing [in MOBERO] is much better for him than seeing the pointer move. It has made a world of a difference for him, no doubt about it, and he also says that himself."* (Anders' mother). However, visualizing the time also caused unexpected outcomes. First, several families reported that the child had to get used to the time element, which caused some issues such as one family explaining how their child hardly had time to say goodnight "*[...] he hardly had time for a hug because he had to rush and tap it [MOBERO]"* (Anders' mother). Though the parents mostly told these situations as funny stories, it does indicate the time element in MOBERO caused problems. Furthermore, three families explained that the time element stressed their child as exemplified by Brian's mother "*[...] and then he has to put his clothes on, which always makes him super frustrated because [putting on] the socks are challenging both on time*

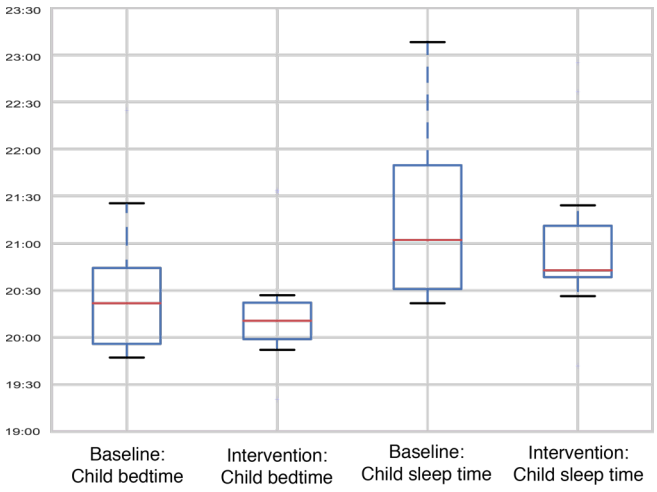

Figure 5. Boxplot of the parent reported child bedtime and sleep time for both baseline and intervention period.

[using MOBERO] and without time, but he has been especially stressed when he had to do it on time" supported by Tom's parents *"(Mother) He told me that he got stressed by the clock. (Father) Yes, that is right, especially when he eats, then he puts the phone away, he does not want to see the time"*. Furthermore, the time combined with the rewards also caused unexpected negative consequences as highlighted by Brian's mother "*It is very often, not in the evening, but in the morning it very often ends up being very much about the medals. It very quickly becomes about doing things as fast as possible, and if the time goes too fast he becomes enormously sad and angry - especially with the clothing [activity] because it was set a little too fast"*.

Positive Effects of using Rewards

The rewards during both morning and bedtime routines motivated the child as explained by Sebastian's dad saying "*[...] but I also think that we should not be afraid to say that the reward in the end is the motivational factor, he has put great pride in putting the stars up [before bedtime]*", which is also supported by Rebecca and Owen's mother *"[...] the reward system and the [fluorescent] stars certainly means something*". Several families empathized that their child did not seem to lose interest in the morning rewards during the intervention period "*No, it still keeps him focused. This morning he also just had to see how many points he got, even after 14 days it was interesting for him to see how many points there were.*" (Anders' mother). However, for some children, the virtual rewards in the morning did not motivate them: e.g. "*I don't think that Fiona experienced the [virtual] medals as the same rewards as she does with the [physical] stars [...]. The stars are clearly more motivating [...]. She can see them when she goes to bed, and she is very proud when she earns a star [...]"* (Fiona's mother). Most parents suggested that the physical reward in the evening would always be interesting for their child, as it supports the opportunity to change the reward, e.g. "*I think that it [the bedtime reward system] will always work if you make sure that you agree on a different thing [rewards]. I believe that would work in a longer period because we have previously in periods done that with the reward board over several months. Then we have just exchanged the tasks or rewards and that has worked fine for motivating him"* (Brian's mother).

Children do not Question Routines in MOBERO

Several parents reported that activities/requests that previously would have resulted in conflicts between the child and parent were eliminated by MOBERO: e.g., "*Because it is on the phone he accepts the sequence completely*" (Brian's mother). The parents also mentioned that specific activities that previously had been impossible to ask of the child, were now simply completed without question: e.g., "*I do not have to tell him to wash his hands. Before, he did not want to and there would be a bloody fight if he had to wash his hands – and now he also just does that"* (Simon's mother); and "*He sort of just accepts that we have now ventilated his room and he does not get angry in the same way when he needs to go to bed"* (Brian's mother). These statements support the quantitative results that show that parents experienced less frustration when using MOBERO. Furthermore, it also indicates that the parents did not only become less frustrated because their child became more independent, but also because the children seemed to accept the sequence of routines on the phone, limiting the discussions.

The Children Integrated MOBERO into Their Routines

The parents reported that their child embraced MOBERO very quickly and that it became a help for the child to comprehend the activities around the morning and bedtime routines exemplified by *"In some way he is now more aware of the flow, and it does not come as a shock for him every day that he has to brush his teeth."* (Brian's mother) supported by Anders' mother "*I definitely believe that he feels he has more control*". Furthermore, several of the parents reported that their child was very aware of the phone and established a connection to MOBERO e.g. *"He has talked about it [MOBERO] and he has remembered the phone if we forgot it 'Where is the phone? We can't start without it.' [...]"* (Brian's mother). Another example of this was: "*He also wanted to bring it with him [to his grand-parents], he has also been a little proud of it"* (Simon's mother) and Ander's mother explained that Ander wanted it on his own iPad: "*He asked if he could get it [MOBERO] on his own iPad, because then it was sort of closer to him [...]"*. Ander's mother also told us that Ander's the previous day had said "*He think today is the worst day in his life because you come and pick up the phone"*.

MOBERO Helped the Children Feel More Responsible

Asking the parents about the qualities of MOBERO compared to a similar paper based system, we learned that the children found it engaging in a way a piece of paper was not: e.g., "*Also, it [a paper-based tool] is not involving in the same way, I mean, a piece of paper appeals to something for adults right?"* (Otto's mother) supported by Ander's mother *"So, for him it [technology] is a world he*

knows and one that he thinks is fun". Furthermore, technology also makes the child feel more responsible "*He feels a responsibility in that it is he who is controlling the smartphone in another way than a child can take responsibility of a piece of paper.*" (Otto's mother). Furthermore, the parents' also highlighted elements in MOBERO that would not be possible to do with a piece of paper, such as assisting the child in transitions between tasks "*I have made pictograms for him and things like that [...] but with regards to getting from A to B and making that [transition] smooth, it is clear that the paper can't do that [...]"* (Simon's mother). Several families also emphasized the interactive time and reward element in MOBERO as motivating for the child, though as mentioned in one of the previous subsections this also caused challenges *"[...] Even though there have been some conflicts in relation to the rewards they also encourage him because he is competitive and he does not get that from a piece of paper*" (Brian's mother). According to the ADHD professionals, many children with ADHD are naturally drawn to "screens" due to the high level of stimulation; and that "screen-time" often seems to be a reward in it self. Finally, many families stressed to us that a physical piece of paper would disappear or get destroyed as exemplified by Ryan's mother: "*We have tried several different charts, but after a few days there are torn apart or have vanished. This [MOBERO] is always there, so that is convenient"*

LIMITATIONS AND FUTURE WORK

We want to emphasize that the presented work is not a clinical study, and we do not argue that MOBERO can assist all families with ADHD in the way we experienced in the presented study.

We are furthermore aware, that a limitation in our current work is the relatively low number of participants and the absence of a control condition. However, as children with ADHD are vulnerable users and we are evaluating a novel technology-based approach to assist these children to cope with their deficits, we argue (in line with Klasnja et al. [27]) that it is more important to first uncover potential problems and understand the use of the technology, than to conduct longer and larger efficacy studies. However, as we did design our study to include a baseline period, we used the families as their own controls, allowing us to compare our quantitative and qualitative data from the baseline period against the intervention period.

To address the concern that our results might be due to the novelty of the intervention, we plan to run a prolonged study with families using an improved version of MOBERO based on findings from this work. This new study will focus on investigating the qualities and challenges families experience from using assistive technologies like MOBERO over several months. If this work is successful, then we will work with colleagues in the medical domain to design a randomized controlled trial of MOBERO.

DISCUSSION

We have reported the results of a design process involving ADHD domain professionals and parents of children with ADHD, two pilot studies with families, and a four-week structured user study of MOBERO with 11 families and 13 children with ADHD. From our early design process with ADHD domain professionals we learned that we had to design for the family and not only the child with ADHD, due to the fact that ADHD is highly heritable and many parents might find it hard to provide the structure needed for their child to establish healthy routines. We integrated our findings from our design process and pilot studies into MOBERO and ran a four-week study with 13 children diagnosed with ADHD and their families, to explore how technology can assist in changing family practices around the child's morning and bedtime routines. We showed that MOBERO was associated with lower parental frustration levels and higher child independence during morning and bedtime routines. Furthermore, based on standardized questionnaires we showed a reduction in ADHD symptoms and an improvement in the child's sleep habits. Based on our findings from this process, we now discuss implications for the design of technologies to support families with children with ADHD.

Differences Between Virtual and Physical Rewards

As our findings suggest, both the virtual (morning) and physical (bedtime) rewards positively influenced most of the children. The virtual rewards in the MOBERO morning module were based on how fast or slow a child completed an activity and would give the child between one or four medals. These time-based rewards seemed to motivate the child to complete not just certain activities faster or slower, but also to complete activities that would otherwise have caused a conflict. Interestingly, in the cases where the parents reported that their child was not motivated by the virtual rewards, we saw little or no effect in the parent reported data. This suggests that immediate rewards could be a critical part of the success for assistive technologies like MOBERO for children with ADHD. However, time-based rewards could also have the potential to stress and cause defeats; researchers should take care to include ways to tailor the rewards system to the individual child as suggested above.

Furthermore, several parents emphasized their child took pride in putting up the stars and put significant effort into drawing their rewards on the reward sheet. This suggest that the child valued the physical rewards more than the virtual rewards, and that the rewards being physical and visible were important for the child. It may also have been because the physical rewards were not based on how fast the child completed the bedtime routines: the child did not have to stress about completing the routines as fast as possible, which could have made it more difficult for the child to calm down and fall asleep. Finally, the physical rewards were more closely embedded into existing family dynamics, in representing quality time that the child would spend

playing with their parents. Further work would be necessary to identify which of these factors contributed most to the greater success of the physical rewards.

Assistive Technologies for the ADHD Domain Hold Potential as a Supplement to Existing Treatments

As mentioned in the introduction, traditional ADHD treatments include prescribed medication [21]. However, we believe that there are interesting and unexplored opportunities for HCI researchers to collaborate with ADHD professionals on developing novel technological solutions that supplement the existing treatments. In our study, seven children received medication for their ADHD disorder; nevertheless, we still saw a positive impact for these families, suggesting that MOBERO did provide an effect medication could not provide. As both our own and the few existing studies [34,38,48] within the ADHD domain shows, HCI researchers are in a unique position to contribute with alternative solutions for empowering families and children with ADHD. By involving families and ADHD domain professionals into the design process, HCI researchers are able to identify and evaluate opportunities for technological support in specific situations. Our studies show that these technologies can have a substantial impact on families' everyday life as well as on children's traditional ADHD parameters. We are aware, that setting up and conducting studies similar to the clinical studies within the medical domain is out of scope for most HCI researches. However, smaller tailored studies and involvement of users and ADHD domain professionals in the early phase of assistive technologies are still relevant for the HCI community as these can provide unique insights that larger studies often cannot provide. These insights are important as they enable researchers to understand the qualities and shortcomings of their application, which can help frame the next development and evaluation phase. We do not argue for using technology instead of medication, nor do we claim that technology can benefit children and families in the same way that traditional treatments do. However, we argue for the possibilities of designing and evaluating assistive technologies as a complement to traditional solutions for families and children with ADHD.

Facilitate Tailoring to Family Contexts

From our evaluations we learned that visualizing time and rewards in the MOBERO morning module was beneficial as it assisted the child to stay on track and made the child complete activities faster (or longer i.e. brushing teeth) than they usually did. However, in a few of the early studies we also observed the opposite effect, that the time and rewards caused stress and frustration for the child. Because we had not made it possible to tailor the time and rewards properly to the child's capabilities (realistic duration for him to complete specific tasks), we ended up making the child and parents even more frustrated than they were before, and we caused the child to temporarily experience defeat and failure, as he could not achieve maximum points no matter how hard he tried. The benefits of using rewards as a positive reinforcement to motivate people to change behavior have been extensively documented within the HCI community (e.g. [11,12]). However, to the best of our knowledge, there are not yet any examples within behavior change technologies of positive reinforcement having yielded the opposite effect, as we saw in our study. However, similar scenarios have been found in studies of competitive sports systems, where players or athletes tend to be discouraged and give up if an opponent seems impossible to beat or a goal seems impossible to reach [23,39].

Finally, we learned that every family is different; the ADHD professionals have a saying to support this, "*If you have seen one child with ADHD, you have seen one child with ADHD*". Thus technologies to support habit formation for families should support tailoring at least in terms of parameter settings for parents in order to make it possible to adjust, e.g. sequences and timings to fit the child and the specific practices in the family.

Ethical Considerations

It was an ethical challenge to remove MOBERO from the families at the end of the study, as many expressed a high desire to keep it. However, this was research software and not robust or flexible enough to run long term without significant technical support, which was not possible to provide. All families were aware when volunteering for the study that the deployment would only be for a month. We plan to provide a free version of MOBERO to those families who are interested when we have implemented improvements based on the findings of this study.

CONCLUSIONS

In this paper we presented MOBERO, a smartphone-based system for supporting families of children with ADHD during morning and bedtime routines. MOBERO was designed through the involvement of both parents and ADHD professionals, and was evaluated in the wild with 11 families of children with ADHD over two weeks. Our qualitative findings supported our quantitative findings in that they showed MOBERO significantly reduced the parent' frustration level and improved the parent rated child independence level. Furthermore, by using standardized questionnaires we saw a significant improvement in the child's parent-reported ADHD symptoms and the child's sleep habits. By tailoring and designing technologies for the whole family, we believe that HCI researchers are in a unique position to improve the quality of life for families and children with ADHD by supplementing traditional medical treatments with assistive technology.

Acknowledgements

We thank all of the families for participating in our study. Furthermore, we want to thank Center for ADHD, Lene Ruge Møller, Lotte Fensbo, Line Møller Sletting, Anne Virring Sørensen, and Per Hove Thomsen for their valuable insights and feedback.

REFERENCES

1. A. D. Anastopoulos, G. J. DuPaul, and R. A. Barkley. 1991. Stimulant medication and parent training therapies for attention deficit-hyperactivity disorder. *Journal of Learning Disabilities* 24, 4: 210–218.
2. Sonia M. Arteaga, Mo Kudeki, Adrienne Woodworth, and Sri Kurniawan. 2010. Mobile System to Motivate Teenagers' Physical Activity. *Proceedings of the 9th International Conference on Interaction Design and Children*, ACM, 1–10. http://doi.org/10.1145/1810543.1810545
3. William J. Barbaresi, Robert C. Colligan, Amy L. Weaver, Robert G. Voigt, Jill M. Killian, and Slavica K. Katusic. 2013. Mortality, ADHD, and Psychosocial Adversity in Adults With Childhood ADHD: A Prospective Study. *Pediatrics* 131, 4: 637–644. http://doi.org/10.1542/peds.2012-2354
4. Jakob E. Bardram, Mads Frost, Károly Szántó, Maria Faurholt-Jepsen, Maj Vinberg, and Lars Vedel Kessing. 2013. Designing Mobile Health Technology for Bipolar Disorder: A Field Trial of the Monarca System. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 2627–2636. http://doi.org/10.1145/2470654.2481364
5. Jared S. Bauer, Sunny Consolvo, Benjamin Greenstein, et al. 2012. ShutEye: Encouraging Awareness of Healthy Sleep Recommendations with a Mobile, Peripheral Display. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 1401–1410. http://doi.org/10.1145/2207676.2208600
6. Joseph Biederman and Stephen V Faraone. 2005. Attention-deficit hyperactivity disorder. *The Lancet* 366, 9481: 237–248. http://doi.org/10.1016/S0140-6736(05)66915-2
7. Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2: 77–101. http://doi.org/10.1191/1478088706qp063oa
8. Tracy G. Cassels. 2013. ADHD, Sleep Problems, and Bed Sharing: Future Considerations. *The American Journal of Family Therapy* 41, 1: 13–25. http://doi.org/10.1080/01926187.2012.661653
9. Eun Kyoung Choe, Sunny Consolvo, Nathaniel F. Watson, and Julie A. Kientz. 2011. Opportunities for Computing Technologies to Support Healthy Sleep Behaviors. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 3053–3062. http://doi.org/10.1145/1978942.1979395
10. Eun Kyoung Choe, Bongshin Lee, Matthew Kay, Wanda Pratt, and Julie A. Kientz. 2015. SleepTight: Low-burden, Self-monitoring Technology for Capturing and Reflecting on Sleep Behaviors. *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, ACM, 121–132. http://doi.org/10.1145/2750858.2804266
11. Sunny Consolvo, Predrag Klasnja, David W. McDonald, et al. 2008. Flowers or a Robot Army?: Encouraging Awareness & Activity with Personal, Mobile Displays. *Proceedings of the 10th International Conference on Ubiquitous Computing*, ACM, 54–63. http://doi.org/10.1145/1409635.1409644
12. Sunny Consolvo, David W. McDonald, and James A. Landay. 2009. Theory-driven Design Strategies for Technologies That Support Behavior Change in Everyday Life. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 405–414. http://doi.org/10.1145/1518701.1518766
13. Sunny Consolvo, David W. McDonald, Tammy Toscos, et al. 2008. Activity Sensing in the Wild: A Field Trial of Ubifit Garden. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 1797–1806. http://doi.org/10.1145/1357054.1357335
14. Samuele Cortese, Stephen V. Faraone, Eric Konofal, and Michel Lecendreux. 2009. Sleep in Children With Attention-Deficit/Hyperactivity Disorder: Meta-Analysis of Subjective and Objective Studies. *Journal of the American Academy of Child & Adolescent Psychiatry* 48, 9: 894–908. http://doi.org/10.1097/CHI.0b013e3181ac09c9
15. Søren Dalsgaard, Preben Bo Mortensen, Morten Frydenberg, and Per Hove Thomsen. 2013. Long-term criminal outcome of children with attention deficit hyperactivity disorder. *Criminal behaviour and mental health: CBMH* 23, 2: 86–98. http://doi.org/10.1002/cbm.1860
16. Julia F. Dewald, Anne M. Meijer, Frans J. Oort, Gerard A. Kerkhof, and Susan M. Bögels. 2010. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Medicine Reviews* 14, 3: 179–189. http://doi.org/10.1016/j.smrv.2009.10.004
17. Douglas E. Faries, Ilker Yalcin, Donald Harder, and John H. Heiligenstein. 2001. Validation of the ADHD Rating Scale as a clirlician administered and scored instrument. *Journal of Attention Disorders* 5, 2: 107–115. http://doi.org/10.1177/108705470100500204
18. Michael W. Firmin and Annie Phillips. 2009. A Qualitative Study of Families and Children Possessing Diagnoses of ADHD. *Journal of Family Issues* 30, 9: 1155–1174. http://doi.org/10.1177/0192513X09333709
19. Goldman LS, Genel M, Bezman RJ, Slanetz PJ, for the Council on Scientific Affairs, and American Medical

Association. 1998. DIagnosis and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *JAMA* 279, 14: 1100–1107. http://doi.org/10.1001/jama.279.14.1100

20. V. A. Harpin. 2005. The effect of ADHD on the life of an individual, their family, and community from preschool to adult life. *Archives of Disease in Childhood* 90 Suppl 1: i2–7. http://doi.org/10.1136/adc.2004.059006

21. Lily Hechtman and Brian Greenfield. 2003. Long-term use of stimulants in children with attention deficit hyperactivity disorder: safety, efficacy, and long-term outcome. *Paediatric Drugs* 5, 12: 787–794.

22. Inseok Hwang, Chungkuk Yoo, Chanyou Hwang, et al. 2014. TalkBetter: Family-driven Mobile Intervention Care for Children with Language Delay. *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*, ACM, 1283–1296. http://doi.org/10.1145/2531602.2531668

23. Mads Møller Jensen, Majken Kirkegaard Rasmussen, and Kaj Grønbæk. 2013. Exploring Opponent Formats. In *Entertainment Computing – ICEC 2013*, Junia C. Anacleto, Esteban W. G. Clua, Flavio S. Correa da Silva, Sidney Fels and Hyun S. Yang (eds.). Springer Berlin Heidelberg, 48–60. Retrieved September 22, 2015 from http://link.springer.com/chapter/10.1007/978-3-642-41106-9_6

24. Matthew Kay, Eun Kyoung Choe, Jesse Shepherd, et al. 2012. Lullaby: A Capture & Access System for Understanding the Sleep Environment. *Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, ACM, 226–234. http://doi.org/10.1145/2370216.2370253

25. Julie A. Kientz, Matthew S. Goodwin, Gillian R. Hayes, and Gregory D. Abowd. 2013. Interactive Technologies for Autism. *Synthesis Lectures on Assistive, Rehabilitative, and Health-Preserving Technologies* 2, 2: 1–177. http://doi.org/10.2200/S00533ED1V01Y201309ARH004

26. Hyungsin Kim, Anya Kogan, Chandan Dasgupta, Michael Misha Novitzky, and Ellen Yi-Luen Do. 2011. Grocery Hunter: A Fun Mobile Game for Children to Combat Obesity. *Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction*, ACM, 317–320. http://doi.org/10.1145/1935701.1935775

27. Predrag Klasnja, Sunny Consolvo, and Wanda Pratt. 2011. How to Evaluate Technologies for Health Behavior Change in HCI Research. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 3063–3072. http://doi.org/10.1145/1978942.1979396

28. Torkel Klingberg, Elisabeth Fernell, Pernille J. Olesen, et al. 2005. Computerized Training of Working Memory in Children With ADHD-A Randomized, Controlled Trial. *Journal of the American Academy of Child & Adolescent Psychiatry* 44, 2: 177–186. http://doi.org/10.1097/00004583-200502000-00010

29. James J. Lin, Lena Mamykina, Silvia Lindtner, Gregory Delajoux, and Henry B. Strub. 2006. Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game. In *UbiComp 2006: Ubiquitous Computing*, Paul Dourish and Adrian Friday (eds.). Springer Berlin Heidelberg, 261–278. Retrieved April 16, 2014 from http://link.springer.com/chapter/10.1007/11853565_16

30. Salvatore Mannuzza, Rachel G. Klein, and John L. Moulton. 2008. Lifetime criminality among boys with ADHD: a prospective follow-up study into adulthood using official arrest records. *Psychiatry research* 160, 3: 237–246. http://doi.org/10.1016/j.psychres.2007.11.003

31. Greta M Massetti, Benjamin B Lahey, William E Pelham, et al. 2008. Academic achievement over 8 years among children who met modified criteria for attention-deficit/hyperactivity disorder at 4-6 years of age. *Journal of abnormal child psychology* 36, 3: 399–410. http://doi.org/10.1007/s10802-007-9186-4

32. Robert J. McInerney and Kimberly A. Kerns. 2003. Time Reproduction in Children With ADHD: Motivation Matters. *Child Neuropsychology* 9, 2: 91–108. http://doi.org/10.1076/chin.9.2.91.14506

33. J. A. Owens, A. Spirito, and M. McGuinn. 2000. The Children's Sleep Habits Questionnaire (CSHQ): psychometric properties of a survey instrument for school-aged children. *Sleep* 23, 8: 1043–1051.

34. Laura Pina, Kael Rowan, Asta Roseway, Paul Johns, Gillian R. Hayes, and Mary Czerwinski. 2014. In Situ Cues for ADHD Parenting Strategies Using Mobile Technology. *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*, ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 17–24. http://doi.org/10.4108/icst.pervasivehealth.2014.254958

35. Guilherme Polanczyk, Maurício Silva de Lima, Bernardo Lessa Horta, Joseph Biederman, and Luis Augusto Rohde. 2007. The worldwide prevalence of ADHD: a systematic review and metaregression analysis. *The American Journal of Psychiatry* 164, 6: 942–948. http://doi.org/10.1176/ajp.2007.164.6.942

36. Ruth Segal. 1998. The Construction of Family Occupations: A Study of Families with Children Who

Have Attention Deficit/Hyperactivity Disorder. *Canadian Journal of Occupational Therapy* 65, 5: 286–292. http://doi.org/10.1177/000841749806500506

37. Petr Slovák, Ran Gilad-Bachrach, and Geraldine Fitzpatrick. 2015. Designing Social and Emotional Skills Training: The Challenges and Opportunities for Technology Support. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, ACM, 2797–2800. http://doi.org/10.1145/2702123.2702385

38. Tobias Sonne and Kaj Grønbæk. 2015. Designing Assistive Technologies for the ADHD Domain. Accepted for publication in *Pervasive Computing Paradigms for Mental Health*. Springer International Publishing.

39. Tobias Sonne and Mads Møller Jensen. 2014. Race By Hearts. In *Entertainment Computing – ICEC 2014*, Yusuf Pisan, Nikitas M. Sgouros and Tim Marsh (eds.). Springer Berlin Heidelberg, 125–132. Retrieved March 24, 2015 from http://link.springer.com/chapter/10.1007/978-3-662-45212-7_16

40. Tobias Sonne, Carsten Obel, and Kaj Grønbæk. 2015. Designing Real Time Assistive Technologies: A Study of Children with ADHD. *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction*, ACM, 34–38. http://doi.org/10.1145/2838739.2838815

41. Katarzyna Stawarz, Anna L. Cox, and Ann Blandford. 2015. Beyond Self-Tracking and Reminders: Designing Smartphone Apps That Support Habit Formation. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, ACM, 2653–2662. http://doi.org/10.1145/2702123.2702230

42. Ole Jakob Storebø, Maria Skoog, Pernille Darling Rasmussen, et al. 2014. Attachment Competences in Children With ADHD During the Social-Skills Training and Attachment (SOSTRA) Randomized Clinical Trial. *Journal of Attention Disorders*: 1087054713520220. http://doi.org/10.1177/1087054713520220

43. Enrico Tanuwidjaja, Derek Huynh, Kirsten Koa, et al. 2014. Chroma: A Wearable Augmented-reality Solution for Color Blindness. *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, ACM, 799–810. http://doi.org/10.1145/2632048.2632091

44. Carolyn Webster-Stratton and M. Jamila. 2010. Parents, teachers, and therapists using child-directed play therapy and coaching skills to promote children's social and emotional competence and build positive relationships. In *Play therapy for preschool children*. American Psychological Association, Washington, DC, US, 245–273.

45. Peter M. Wehmeier, Alexander Schacht, and Russell A. Barkley. 2010. Social and Emotional Impairment in Children and Adolescents with ADHD and the Impact on Quality of Life. *Journal of Adolescent Health* 46, 3: 209–217. http://doi.org/10.1016/j.jadohealth.2009.09.009

46. Orad Weisberg, Ayelet GalOz, Ruth Berkowitz, et al. 2014. TangiPlan: Designing an Assistive Technology to Enhance Executive Functioning Among Children with Adhd. *Proceedings of the 2014 Conference on Interaction Design and Children*, ACM, 293–296. http://doi.org/10.1145/2593968.2610475

47. World Health Organization. 1992. *The ICD-10 classification of mental and behavioural disorders : clinical descriptions and diagnostic guidelines*. Geneva : World Health Organization. Retrieved November 22, 2014 from http://apps.who.int//iris/handle/10665/37958

48. Oren Zuckerman, Ayelet Gal-Oz, Neta Tamir, and Daphne Kopelman-Rubin. 2015. Initial Validation of an Assistive Technology to Enhance Executive Functioning Among Children with ADHD. *Proceedings of the 14th International Conference on Interaction Design and Children*, ACM, 299–302. http://doi.org/10.1145/2771839.2771901

49. Mental Health Surveillance Among Children — United States, 2005–2011. Retrieved May 21, 2015 from http://www.cdc.gov/mmwr/preview/mmwrhtml/su6202a1.htm?viewType=Print&viewClass=Print

50. Validity and clinical feasibility of the ADHD rating scale (ADHD-RS) A Danish Nationwide Multicenter Study - Szomlaiski - 2008 - Acta Pædiatrica - Wiley Online Library. Retrieved September 9, 2015 from http://onlinelibrary.wiley.com/enhanced/doi/10.1111/j.1651-2227.2008.01025.x/