TangiPlan: Designing an Assistive Technology to Enhance Executive Functioning Among Children with ADHD

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ABSTRACT
Children with Attention Deficit and Hyperactivity Disorder (ADHD) experience a deficit in cognitive processes responsible for purposeful goal-directed behaviors, known as executive functioning (EF). In an effort to improve EF, we are developing TangiPlan – a set of tangible connected objects that represent tasks children perform during their morning routine. We describe the initial stages of a user-centered design process, consisting of interviews with both domain experts and potential users, followed by paper prototyping. Based on our findings, we formulated preliminary design principles for EF assistive technology: facilitate organization, time management and planning; involve caregivers in the process, but strive to reduce conflict; implement intervention techniques suggested by experts; avoid distraction by mobile phones; avoid intrusion. We discuss the benefits of implementing these principles with a tangible interface, present our prototype design, and describe future directions.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Prototyping, User-centered design.* K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for persons with disabilities.*

Keywords
ADHD; Executive Functions; Time Management; Children; Tangible; Assistive Technology.

1. INTRODUCTION
Attention Deficit and Hyperactivity Disorder (ADHD), estimated at 3%-7% in school-age children, is reflected in a persistent pattern of inattention and/or hyperactivity-impulsivity [1]. Inattention may manifest in academic, occupational, or social situations. Individuals with this disorder may fail to give close attention to details or may make careless mistakes in schoolwork or other tasks. They may also have difficulties sustaining attention in tasks, and often find it hard to persist with a task until completion. They are easily distracted and often forgetful in daily activities [1].

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Central to the meaning of ADHD is a deficit in cognitive processes responsible for ongoing, purposeful, goal-directed behaviors, known as Executive Functioning (EF) [7, 16]. EF includes inhibition (self-control, self-regulation), cognitive flexibility and working memory [11], problem-solving, reasoning and planning [3]. Behavioral manifestations of poor EF are Organization, Time Management, and Planning (OTMP) difficulties, which adversely affect children's functioning and persist through adulthood [2].

Besides medication, treatment for ADHD typically is directed at enhancing cognitive and learning skills [e.g. 17], emphasize social and emotional functioning [e.g. 6] or both [10]. Since OTMP problems reflect a performance rather than skill deficit, successful interventions include behavior modification that rewards goal-based behaviors, which can increase the occurrence of these behaviors and ostensibly reinforce the behavior chain linked to goal attainment as well [5].

We set out to design an assistive technology, aimed to help middle school children with ADHD improve EF. We based our prototype, called TangiPlan, on strategies employed by ADHD clinicians. TangiPlan is currently being designed in an iterative process. In this paper we describe the initial stages of the design process, consisting of interviews with domain experts and users, followed by paper-prototyping. We present preliminary design principles, and explain how we are implementing them into a tangible prototype.

2. RELATED WORK
Several assistive technologies aimed to enhance executive functioning were presented in recent years, though not specifically targeting children with ADHD. ProcedurePal [4] is a smartphone application for rehearsing common daily tasks. Tasks are defined and divided into smaller steps, each represented by an image. Users view the images to learn how to perform the task. TaskTracker [9] is a smartphone application enabling users to define tasks for themselves, set alarms and motivational messages, and then track actual progress. Basic Calendar [12] is a smartphone application that enables task-tracking through a customized calendar interface. It also enables others to remotely add tasks for the user. Time Timer (http://www.timetimer.com) is a physical timer with a red disc that disappears as time elapses, making it easier to visualize how much time is left for completing a task. Watchminder (http://watchminder.com) is a vibrating wrist watch for setting alarms.

While these systems address various aspects of executive functions, some of them are intrusive, often displaying reminders and alarms. It is unclear whether children with ADHD would be willing to use such systems. Furthermore, when the system is a smartphone application, children with ADHD might get distracted by other applications on their phone. Hence, we strive to develop a non-intrusive tangible system.

3. SYSTEM DESIGN PROCESS

3.1 Interviewing Domain Experts

Our first step was consulting experts in the field of ADHD.

3.1.1 Participants

Three highly experienced educational psychologists and a psychiatrist, all specializing in treating children with ADHD, were interviewed.

3.1.2 Method

Participants were asked to list common challenges that middle school children with ADHD are facing, and describe current intervention and treatment techniques.

3.1.3 Results and Discussion

Participants explained that children with ADHD experience academic, behavioral, emotional, and social difficulties. However, many intervention programs focus only on learning skills. A prevalent challenge concerns lack of efficiency in maintaining daily routines, due to a deficit in executive functioning. This challenge is equally prevalent among boys and girls. Therefore, we decided to focus on enhancing efficiency in daily routines. Currently, in order to increase efficiency, children are advised to: (1) Plan a daily schedule and allocate time for each activity. (2) Separate complicated tasks into smaller, more manageable ones. (3) Write to-do lists and reminders. (4) Ask for assistance from caregivers or friends. (5) Use a stop-watch to track task completion time. Participants also stressed the importance of caregiver involvement – caregivers are known to play a crucial role in children's motivation and ability to overcome challenges.

3.2 Interviewing Potential Users

Our second step was interviewing potential users in order to learn more about their challenges with daily routines, and particularly how they attempt to overcome these challenges.

3.2.1 Participants

Six child-parent pairs (children: 4 males, 2 females; parents: 1 father, 5 mothers) were interviewed. All children were 12 years old, and currently receiving treatment for ADHD. They were referred to the study by their psychologist.

3.2.2 Method

Interviews were conducted at families' homes. Parent and child were interviewed separately for approximately 30 minutes each. The interviews were recorded; the audio recordings were later transcribed. Two researchers independently analyzed the transcriptions to identify emerging common themes.

3.2.3 Results and Discussion

Similarly to experts, parents described a lack of efficiency in children's ability to follow daily routines (*"He goes around the house without planning ahead; he just goes from one room to another"*). The morning routine was considered particularly important (*"If his morning starts badly, he would be on edge all day"*). Furthermore, this specific routine was relatively similar among all participants. Therefore, we decided to focus on the morning routine. Inefficiency often results in wasting too much time on one task, then having to rush through the remaining tasks (*"He can spend 10 minutes tying his shoes, and would only carry on when I call him"*). Most parents said they constantly have to monitor their children, rush them when necessary, and verify they don't forget anything. Consequently, the atmosphere in the house could become tense and unpleasant (*"I want to start my day without my mom shouting at me"*).

Morning inefficiency appears to bother parents more than children (*"When I forget my key I say to myself 'I am so stupid', but two minutes later I forget all about it"*). Some parents are extremely bothered, so even though they wish their children would become independent, they perform tasks for them to ensure successful completion (*"I never organize my school bag; my mom does that for me"*). Interestingly, children don't mind keeping their parents involved in their morning routine, mainly because this involvement compels them to be ready on time (*"The only thing that makes me go out of bed is mom standing at the door"*).

When asked which techniques are employed to increase efficiency, most children explained that they tried writing notes, but found it tedious and irrelevant (*"Why should I write notes on paper when I have my mobile device? That's stupid"*). Most of them tried setting reminders and various timers on their phone, but perceived those as annoying (*"I'm tired and cranky in the morning, I don't want something beeping at me all the time"*). Moreover, mobile phones could potentially become a distraction (*"If I open my phone and see I have new massages, there is no way I can ignore them. I can spend 5-10 minutes in conversation and mom gets angry at me"*). Accordingly, most children are not allowed to use their mobile phone in the morning.

Based on the interviews with both experts and users, we formulated preliminary design principles for an EF assistive technology: (1) Facilitate organization, time management and planning. (2) Involve caregivers in the process, as they are the main agents of change, but strive to reduce conflict. (3) Implement intervention techniques suggested by experts. (4) Avoid distraction by mobile phones. (5) Avoid intrusion.

3.3 Initial Design

Our third step was implementing the design principles in TangiPlan – a system of tangible connected objects. Each object represents a task that needs to be performed in the morning. Using TangiPlan consists of two main stages: planning and execution.

Planning: during this stage, which occurs at the previous evening, parent and child divide the morning routine into small tasks, and allocate time for completing each one. This strategy corresponds with the suggestions of experts for increasing efficiency. Once the list of tasks is ready, the child pairs each task with a tangible object, and then places each object at the location where the task is supposed to be performed. The benefits of using a tangible interface are three-fold: first, avoiding potential distraction by mobile phones. Second, the tangible objects act as physical non-intrusive reminders for performing the corresponding tasks. Third, the tangible objects are location-specific, and location has been shown to enhance cognitive processes like memory and learning

[8, 13, 14]. Thus, the use of location-specific tangible objects potentially has cognitive advantages.

Execution: during this stage, which occurs the next morning, the child activates each object at the beginning of the task, and deactivates it when the task is complete. While active, the object intuitively indicates elapsing time, assisting the child with time-management. The order of performing the various tasks is flexible: a certain task could be performed first one day, and last another day. This flexibility allows the child to change the internal order of tasks according to external circumstances, as well as maintain a sense of autonomy. Autonomy has been shown to positively affect task perseverance among youth with ADHD [15].

The tangible objects are connected to a web-based interface to enable real-time monitoring of task-completion. Real-time monitoring enables parents to remain informed from a distance, hopefully reducing conflict. Moreover, real-time monitoring can remind children to complete overlooked tasks before leaving the house. In the long run, the system could provide analytical performance-based information, for example suggestions to allocate more or less time to a certain task.

3.4 Paper Prototyping

Our fourth step was creating a paper prototype of the system in order to validate our initial design. The paper prototype consisted of simple cardboard cubes, 3cmX3cmX4cm in size. These are the minimal dimensions required for the desired electronic components. We also created a document for pairing tasks with objects. The document consisted of a table with four columns: number, name of task, time per task, remarks.

Our research questions were: (1) Can users pair morning tasks with tangible objects? (2) On average, how many tasks are included in the morning routine of a child with ADHD? (3) Where would children choose to place the objects?

3.4.1 Participants

Three child-parent pairs participated in the study. They were recruited from the sample that was previously interviewed, based on availability. All children were males and parents were females.

3.4.2 Method

A research assistant visited participants in their home, and presented them with the paper prototype. First, participants were asked to pair tasks with objects, using the table. Then, the child placed the cardboard cubes in the locations where corresponding tasks would be performed the next morning. Lastly, parents and children were interviewed regarding this experience and their general impression of TangiPlan. The interviews were recorded; the recordings were later transcribed and independently analyzed by two researchers to identify emerging common themes.

3.4.3 Results and Discussion

Overall, the results were promising: parents and children liked the general concept, and found it relatively easy to pair tasks with cardboard cubes. They usually listed 12-15 tasks in the table, having learned from past experience to divide the morning routine into micro-tasks, for example: *"wear shoes"*, *"take house keys"*.

The cardboard cubes were placed by children in various locations around the house, for example: near the sink in the bathroom or inside a shoe (see Figure 1). We learned that the tangible objects should be durable. Moreover, several cubes were placed in shared spaces, which are also used by parents and siblings as part of their own morning routine. Therefore, we should prevent accidental activation, and refrain from disturbing other family members.

Figure 1. Locations where the tangible objects of TangiPlan would be placed: near the sink (left) and inside a shoe (right).

3.5 The TangiPlan Prototype Design

Our fifth step was designing the tangible objects. They were designed as a 3D pyramid, the wide base ensuring steadiness. A nano-Arduino board, a WiFi board, a LED matrix, and a battery are embedded inside the object. The entire front panel is transparent to allow LED lighting to be easily observed from several angles (see Figure 2).

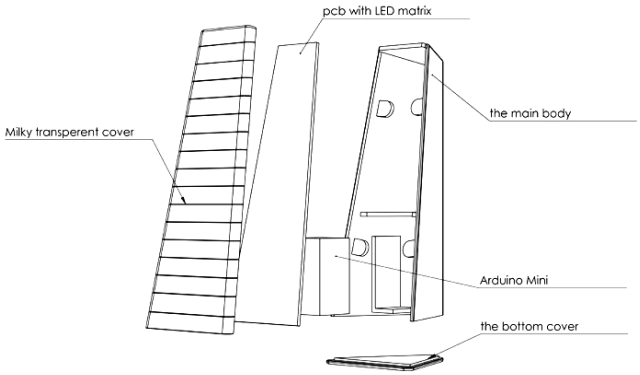

Figure 2. Design of the tangible object of TangiPlan.

The TangiPlan system is comprised of multiple objects, each intended to represent a single task in the child's morning routine. All objects are identical to allow interchangeability between them, and thus flexibility. Our main goal is facilitating organization, time-management and planning. Organization is supported by physically placing objects at intended locations for performing tasks. Time-management is supported by the interaction with the object – as time elapses, white light flows across the front cover from top to bottom, resembling a "digital hourglass". When the allocated time for a task is up, red light begins to flow in the opposite direction. Planning is supported by pairing tasks with objects, and allocating time intervals for completing each task.

We are currently designing additional interactions to support the remaining design principles and considerations. For example, objects will light up only after manual activation by the child, thus remaining relatively unnoticeable for other family members.

Future work includes designing additional components of the system, implementation of a web-based interface and analytical tools, as well as conducting user studies to evaluate the usability and effectiveness of TangiPlan.

4. CONCLUSION

Children with ADHD experience a deficit in executive functioning (EF). We set out to design an EF assistive technology, intended to improve efficiency during morning routines. Our first step was consulting experts to learn which strategies they currently employ. Our second step was interviewing potential users to learn more about their specific challenges. Based on our findings, we formulated preliminary design principles for an EF assistive technology: (1) Facilitate organization, time management and planning. (2) Involve caregivers in the process, but strive to reduce conflict. (3) Implement intervention techniques suggested by experts. (4) Avoid distraction by mobile phones. (5) Avoid intrusion. Our third step was implementing these principles in an initial design. We chose a tangible interface, which offers unique benefits for children with ADHD: association with location, minimal distraction and intrusion. Our fourth step was validating the initial design with a paper prototype. Our fifth step was designing 3D tangible objects to represent tasks children perform during their morning routine.

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