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DEVELOPING AND UTILIZING A SMART, INSTRUMENTED FIDGET TO BETTER UNDERSTAND FIDGETING AND ITS RELATIONSHIP WITH COGNITIVELY DEMANDING ACTIVITIES

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by

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Abstract

Developing and Utilizing a Smart, Instrumented Fidget To Better Understand Fidgeting and its Relationship with Cognitively Demanding Activities

by

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My dissertation research concerns the research space of fidget objects. My work includes the design, construction, and testing of a smart fidget that allows for the collection of detailed logs of fidgeting pattern to support fidgeting research. Due to the recent popularity of fidget objects such as fidget spinners and fidget cubes, the general public is increasingly wondering whether fidgeting is beneficial or detrimental, which in turn has generated more interest in this topic among academics. I believe that smart fidgets can provide deeper insights into fidgeting patterns and behaviors than can be obtained from traditional fidgeting research methodologies by recording of time stamped traces of fidgeting interactions. Toward that end, I led the development of an instrumented fidget object called the *Fidgetato*.

This dissertation covers the overall trajectory of my work concerning this smart fidget object. First, I discuss my research into children's fidget object preferences. This research subsequently informed the design of the smart fidget. Then, I explain the design decisions for the *Fidgetato* along with it's preliminary testing. Following that, I discuss research on adult fidgeting preferences done by analyzing a pre-existing online dataset on Tumblr. Finally, I present a study on the effects of fidgeting on cognitively

demanding activities. This study was conducted to validate the design and efficacy of the *Fidgetato* for fidgeting research. Not only did it confirm the efficacy and design of the *Fidgetato* as a research tool but it also provided data that enabled me to answer questions that could not have been answered using traditional fidgeting methodologies. It further validated my design by finding no impairment to focus and retention when fidgeting with the *Fidgetato* and engaging in cognitively demanding tasks. Overall, my contribution to the field of Human Computer Interaction is the introduction of this smart, instrumented fidget into the target domain of fidget object use, improving basic understanding of this behavior with my studies and with the introduction of this new research tool.

To my parents, thank you for the constant love, support, and inspiration.

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Chapter 1

Introduction

1.1 Introduction

My research is in the field of Human Computer Interaction, in particular tangible computing, and my core contribution is specifically in the area of smart devices and fidgeting. In this thesis, I set out to create and validate a tool that would aide researchers working in the fidgeting space. The driving questions of this work were:

1. How can technology improve our understanding of fidgeting?

   For the purpose of this dissertation, I refer to fidgeting as repetitive movements which are done without a direct purpose.

2. Can I make a device that tracks fidgeting interactions?

   By fidgeting interactions I mean how someone interacts with an object when fidgeting. As an example, someone could squeeze, twist, or roll an object repetitively. Can I create a device that is able to capture and record some of the ways in which people fidget with it?

3. What are the appropriate affordances to incorporate in such a smart device?

   For my purposes, affordances are ways that the device lends itself to being interacted with. For instance, a stress ball can be squeezed so one of the interactions that it affords you the ability to do with it is squeeze it which makes squeezing one of its affordances. My research question involves identifying which fidgeting interactions to incorporate into my device and making the device have those interactions included within it's affordances.

4. What is an appropriate design for such a smart fidget device?

5. How can I validate this device?

6. What new insights can I obtain by utilizing this device for research studies on fidgeting?

Studies on fidgeting and its effects often obtain their results by analyzing fly-on-the-wall observations or retrospective information gathered from questionnaires or interviews. Smart fidgets capable of tracking fidgeting interactions in real time could improve our understanding of fidgeting because the rich usage data captured could lead to deeper analysis than these aforementioned methodologies by helping us to answer questions concerning the impacts of fidgeting related to frequency and patterns of use.

Prior to building the smart fidget, I looked at previous studies for guidance criteria to aid me in the design of the smart fidget. Examination of the objects used in previous studies yielded little usable information, as rather than having any criteria that guided their choice of objects, such as looking to include objects with particular interactions or material qualities, most fidgeting studies chose fidget objects that were either popular at the time of the study, like fidget cubes or fidget spinners, or that were on hand [33, 41, 38]. I found several fidget object studies conducted by Karlesky et al. [24, 26, 27] helpful in that they discussed various common fidgeting characteristics, but they fell short of providing guidance on which characteristics would appeal to a broad segment of the population.

Due to this dearth of actionable design information, I decided that I must start by studying the objects with which people choose to fidget, in order to identify preferred fidget item affordances and then utilize this information to design a smart fidget that would appeal to the broadest possible segment of the population. With this in mind, my first study (Chapter 2) focused on isolating the fidgeting interactions that children engaged in and preferred [10]. This study identified preferred fidget item materials and interactions. It also found relationships between certain interactions and activities or emotions like the bi-directional relationship identified between clicking/pressing/tapping and boredom or engaging in cognitively demanding tasks.

Incorporating my first study results into the design of the object, I led the creation of an instrumented fidget (Chapter 3). In the initial stage of planning, I realized rather quickly that using off-the-shelf components for the smart fidget prototype would result in an object that was too large for testing with children. This realization, coupled with how much easier it is (both from an IRB and a participant recruitment perspective) to deal with adults rather than children, led me to shift my focus to adult fidgeting. I decided to lean on the results of the children's study when designing the smart fidget, and then use the resulting fidget to find out how adults interacted with it.

Next, I focused on my design and which interactions should be included. I decided to incorporate affordances for pressing and clicking into my design so that the smart fidget could be used to investigate how people fidget in situations requiring focus and retention, since one of the relationships identified by my previous study involved interactions prevalent when engaging in cognitively demanding activities and fending off boredom. In addition, fidgeting as an aide to focus and retention is the lay claim about fidget use and as such is often the case made for allowing children to have fidget objects in the classroom and adults to use fidget objects while at work. I further decided to include the ability to track squeezing, since it was identified as the most popular interaction in the previous study, and was also found to have a uni-directional relationship with anger. I realized at the onset that it would be impossible to make one object that would be considered "perfect" for everyone, so instead I aimed to make an object that the majority of people would gravitate towards and want to interact with. I worked with Roger Conaster on this project and he built the prototype from my design criteria and specifications. Preliminary testing was conducted on the electronic fidget (*Fidgetato*) and it was deemed suitable for my purposes.

Due to Covid I had to postpone in-person tests with the *Fidgetato*, so I pivoted and adjusted my research plans. Consequently, I chose to analyze a pre-existing online data set that contained hundreds of fidget object submissions (Chapter 4). I chose to do this for two reasons. First, it would provide insights into adult fidget object preferences that could validate my *Fidgetato* design choices or prove useful by providing possible directions to explore during future iterations of the *Fidgetato*. Second, having already done an in-person time intensive multi-step study, analysing a large Tumblr collection of fidget submissions would would give me the opportunity to compare the two and see if insights similar in depth to those obtained with the in-person study were possible.

With the lifting of Covid restrictions, I validated the *Fidgetato* by using it to collect fidgeting data during a study investigating what effect if any fidgeting has on cognitively demanding activities (Chapter 5). My goals were three-fold: 1) validate the design of the *Fidgetato*, 2) test the *Fidgetato* to find out if it would hold up to the rigors of testing and provide real time usage data and 3) analyze the usage data it captured to see if it would allow for deeper insight into usage than is possible from data obtained by relying on participants' recollections of fidgeting or the limited information on fidgeting interactions that can be recorded during a fly-on-the-wall type study. For this project, I worked with Julia Soares who conducted the statistical analysis.

1.2 Dissertation Outline

This dissertation is organized as follows: Chapters 2 presents the study on children's fidget object preferences from which I obtained insights into when, how, why, and with what children fidget. These results informed the design of the smart fidget. The design and initial testing of the smart fidget is detailed in Chapter 3. Chapter

4 discusses my analysis of the online fidget object data set. Chapter 5 presents the findings of the study I ran on the impact of fidgeting on focus and retention. Finally, chapter 6 discusses my conclusions and possible future work.

Each chapter is written as a standalone paper either published or submitted for publication and hence, some of the literature review is similar across the various chapters.

Chapter 2

Identifying Children's Fidget Object Preferences: Toward Exploring the Impacts of Fidgeting and Fidget-Friendly Tangibles

2.1 Introduction

Fidgeting and fidget-friendly tangibles have recently witnessed enormous popularity in markets and research. Though people have long been observed to fidget, dedicated products like fidget spinners, fidget cubes and other fidget items, have served to focus public attention on fidgeting and its potential benefits or disadvantages. However, whether or not fidgeting and fidget objects are beneficial or detrimental is still to be conclusively determined [36]. Popular perception of fidgeting is that it is indicative of inattention or lack of interest [7]. This is such a widely held belief that there are studies that are built on this assumption [14]. However, there is evidence that fidgeting serves various purposes and can be beneficial [4, 33, 41]. Fidgeting, in the form of hand gestures, has been shown to facilitate word retrieval when children are faced with a "tip of the tongue" situation searching for the optimal word answer to a problem [35]. Rather than being an unproductive mental-resource-wasting activity, fidgeting is postulated to regulate focus [8, 12, 31, 38] and has been shown in some cases to increase retention [4].

Research that attempts to study fidgeting often uses pre-existing fidget items that are either readily available, inexpensive, or popular at the time of the study [33, 38, 41]. I argue that alongside studying the effects of fidgeting, one must study the objects people choose to fidget with so that fidget objects suited to their general material and interaction preferences when fidgeting can be used.

I would argue that what is commonly referred to as fidgeting can be divided into two main categories. The first consists of body movements much akin to squirming or repositioning yourself in your chair. Movements in this category do not incorporate interacting with objects and consist of body movements of the head, full body, and appendages. This type of fidgeting is often linked to inattention and/or boredom [14]. The second category of fidgeting refers to repetitive activities with the hands manipulating objects, which are done without a direct purpose. To illustrate, think of the contrast between someone fidgeting in their chair during a long lecture with someone fidgeting with a pen by spinning it around with their thumb and forefinger while in a meeting or working on homework problems.

My study focused on the material qualities and interactions that children gravitate towards when fidgeting with objects, so that these preferences can inform the design of new fidget items or the choice of existing items to incorporate in future fidgeting studies involving children. Since my goal is to analyze children's fidgeting in order to identify the kinesthetic interactions inherent in their fidgeting (i.e. squeezing, twirling, twisting, etc) and the material qualities associated with the items they choose to fidget with, I focused on the second category of fidgeting as outlined above. For the purposes of this study, I define fidget items or objects as items people fidget with such as fidget spinners, pens, stress balls, etc. A fidget item can be anything that is not part of a person's body. Hence, fingers, hair, and legs though often used while fidgeting are not considered fidget items.

Fidgeting should not be confused with playing. For instance, playing catch or video games is not fidgeting as both are more mindful or intentional. Included in my definition of fidgeting are doodling, hair twisting, and repetitive movement of various other body parts. I am interested in these actions as well as the more commonly referred to "fidgeting" actions because I am interested in finding out what movements and interactions that children gravitate towards when fidgeting. For instance, hair twisting or twirling is done with a repetitive rotational motion that could be simulated with a fidget object.

In this thesis, I present the details of my study and discuss the results across multiple dimensions. My study was conducted in five phases that apart from interactions with children, also involved discussions with parents and teachers. Based on the data collected from this study, I present my findings on user fidget item preferences in terms of material qualities, inherent interactions, noise, and more such observations. In addition, I present relationships between preferred fidgeting interactions and certain emotions and activities. Through these results, I show the significance of learning fidget object characteristic preferences and how that knowledge can aid in the exploration of fidgeting and its impacts.

2.2 Motivation

There is increased interest in fidgeting and its possible benefits or disadvantages. Many studies that attempt to answer these questions use existing fidget objects. I think before one can attempt to answer questions related to fidgeting, fidgeting preferences must be identified. I believe that studies that use fidget items with material qualities and interactions that people naturally gravitate towards when fidgeting, will yield organic interactions and therefore more accurate results as opposed to studies which try to encourage use of fidget objects ill suited to their participants' preferences. Therefore, identifying popular fidget item characteristics will enable informed decisions regarding which fidgets to use or make for a given study. In addition, finding connections between emotions experienced or activities engaged in when fidgeting and preferred fidget item characteristics will enable researchers to make fidget item choices aimed at answering more specific questions. Interaction and material preferences catered to the emotions or actions we want to study can be utilized. For instance, testing the effects of fidgeting on diminishing anger would make/use fidget items that incorporate fidget interactions/material qualities that people gravitate towards when angry.

Sometimes people are conscious of their fidgeting behaviors and sometimes they are not, so merely asking about fidget habits might not be sufficient. Children are a unique group to study in that there often people around them, like parents, teachers, and caregivers, who by choice or profession monitor their behavior. These additional sources of observations regarding children's fidgeting item preferences provides additional data points which help create a more complete picture of their preferences. While children will self report fidgeting that they are conscious of, it is from their parents and teachers that we are able to get information regarding fidgeting behaviours that they are not conscious of. For instance, one participant was able to show me the items that she fidgeted with in class, when she was bored or when she was studying. When asked for information regarding fidgeting item preferences and behaviors at times when she was working on a hard problem or really concentrating, she did not have an answer for me. However, her mother, who was often nearby when she was doing homework, was able to tell me easily how she fidgets during that time. I noticed the same with teachers since they are paid in part to monitor their student's behaviors. So by conducting a study around children, I was able to get more data points describing their fidgeting habits and preferences and therefore more robust conclusions.

Children are not as adept at verbalizing what they are thinking and/or feeling as adults. This, in addition to the fact that children's fidget object choices might be limited due to financial or parental constraints or even exposure, prompted me to design the study so that three different approaches were used to gather information about the children's fidget item preferences. First they were asked to show or describe the objects with which they currently fidget. Second, I brought a myriad of fidget objects to the study and encouraged them to interact with them so that perhaps they would discover new preferences. Finally, I had them design their ideal fidget with its inherent materials and interactions, so that they wouldn't be limited by the objects they had already experienced.

2.3 Related Work

While research relating fidgeting to executive function and childhood developmental theories exists, the physiological, developmental or psychological reasons why people tend to fidget and the cultural differences in fidgeting frequency are outside of the scope of my research [6, 30]. Research exploring technology designed to aid in the development of executive function [16, 44] while interesting, is also outside of the scope of this work.

Popular opinion is so inclined to view fidgeting in a negative light that for research at Florida Atlantic University, a prototype was created that alerts the wearer to fidgeting actions, so that he/she can attempt to curtail them [5]. The goal of my project was the opposite of that thesis. Rather than trying to alert the user to fidgeting actions so that they can be controlled or curtailed, my project attempts to identify preferred fidgeting item characteristics so that fidget items can be chosen such that people are naturally more inclined to interact with them.

There is a limited amount of research in the area of fidget object creation. Karlesky and Isbister [24, 26, 27] created fidget objects that they referred to as Fidget Widgets. These Fidget Widgets were playful in nature and created to "selectively modulate affect and shape cognitive state to support a user's productivity and creativity". Unlike Karlesky and Isbister's Fidget Widget research, which was focused on adults, my research is focused solely on the preferences and behaviors of children.

Recent work conducted at Lund University [33], inspired by research that indicated that squeezing a small ball or walking lead to increased creativity [15, 34] postulated that fidgeting might have a similar effect on creativity and looked for a link between fidgeting and increased creativity. After using ready-made store bought fidget items for initial studies, Nyqvist made several prototypes but was unable to definitively prove that one was better than another at fostering creativity. Rather than concentrate on which interactions or materials people might gravitate towards when doing creative work, the study focused on why people fidget and identified four reasons: to focus (engage cognitively), explore (release cognitively), active (engage physically), and relax (release cognitively). Nyqvist's research did not link any of those reasons to preferred interactions or material qualities in fidget items.

In addition to the above-mentioned work, numerous fidget objects, backed by research [20], have been marketed as attention and focus enhancers (i.e, fidget spinners, fidget cubes, etc) for people with attention deficit hyperactivity disorder (ADHD). However, they lack the prior research to inform their design and ensure that they are providing interactions and experiences that children find appealing. Instead, research around these items has focused on whether or not fidgeting with them is beneficial, without ever first researching the needs and preferences of the populations they were intended for.

The primary distinction between the previously mentioned studies and my current research is that I do not seek to build a fidget object or to investigate a current fidget object but rather to inform the design of future fidgeting objects for educational, experimental, and other practical purposes.

2.4 Methods

In collaboration with Committee for Children, I chose a convenience sample of 28 children (10 boys and 18 girls) between the ages of 6 and 11 (see Figure 2.1 for children's age distribution); 24 of their parents; and 2 of their teachers from two different after-school facilities to explore the following questions: Do all children fidget? When (e.g., at school, studying, when angry, sad, etc) and how (e.g., twisting, petting, bouncing, tapping, pinching, etc) do they fidget? What object properties do they gravitate towards? How does fidgeting serve the child (e.g., maintaining focus, regulating emotion, dispelling energy, etc.) What connection, if any, exists between why children fidget and preferred fidget materials and/or interactions?

The children were recruited from the two after-school programs by posting flyers in those facilities advertising the program, and directing interested children/adults

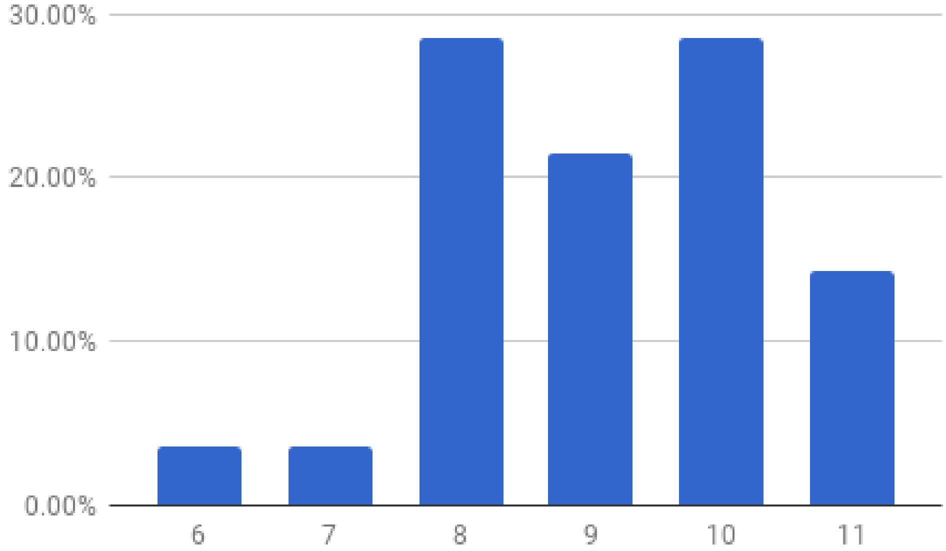


Figure 2.1: Age distribution of participating children
(median age: 9)

to the front office, where a more detailed informational sheet was provided. If interested in having their children participate in the study, the parents then needed to turn in a signed permission form. By signing the form and having their child participate, the parent agreed to take part in two phases of the study as well, Meet & Greet and Group Session. Due to the nature of the study, I decided to allow siblings and others take part in the process even if they were not strictly in the target age range (8-10).

While I never asked any questions directly relating to socio-economic status, parents educational background, or family makeup, through information obtained from conversations with the parents, teachers and the children themselves it became clear that I had a very diverse cross-section of children taking part in the study. For instance, at least two of the children were living in a homeless shelter with their mother at the time of the study, another was living with her mother in a trailer without running water, and several of the children were from what were clearly affluent homes. Six of the children had at least one parent who was pursuing his/her Bachelors degree at the time of the study. Several children came from one-parent homes and at least one child came from a two-parent same sex home. In addition, at least two of the students in the study have been diagnosed with ADHD.

I conducted a multi-phase study utilizing established user-centered design practices. Guided by children-specific usability testing [11, 19], I conducted a series of interviews, observation and design workshops [28] with the children to gather the necessary information to answer my research questions. Due to the often subconscious nature of fidgeting, I also chose to include the parent(s) and teachers of the children participating in this study in order to capture more complete data regarding the children's fidgeting habits and preferences.

There were five phases to the study: Exploration, Meet & Greet, Group sessions, Brainstorming, and Teacher Interview. Each phase is outlined in more detail below. The children took part in the Exploration and Brainstorming while their parents took part in Meet & Greet and Group sessions. Exploration, Meet & Greet, Group sessions, and Brainstorming were done with small groups of 5-to-8 participants. Teacher Interview was done one-on-one.

Figure 2.2: Examples of some of the fidget items supplied during EXPLORATION.

2.4.1 Exploration

In the Exploration phase, I obtained information from children about their fidgeting preferences and behaviors. This phase was done in two parts. During the first part, I asked each of the children whether or not they fidget and if they do, to tell me the associated times and frequency, possible reasons, and inherent materials and interactions of the fidget items that they used. If the child had the item with him/her, I took a picture of the fidget item and recorded a video of the child interacting with it. If the child didn't have the item(s) with him/her, I asked him/her to describe the item(s) in detail. During the second part, I used several bins containing an assortment of fidget items (see Figure 2.2). There were 29 different types of fidget items, each of which could have variations in color and shape, with a total combination of over 90 unique fidget items from which the children could choose. I instructed each child to pick a favorite fidgeting item(s) from the bin. The children had complete freedom of choice and were encouraged to touch and manipulate all of the fidgets during this exploration. At the end of the session, I asked each child to tell me what their favorite fidget item(s) were, and why and when they thought they would use them.

2.4.2 Meet & Greet

The main purpose of Meet & Greet was to gather some preliminary information and get parental buy-in for the field study. In order to do this, I arranged to have food and drinks at the end of the day when the parents were scheduled to pick their children up from the after-school program. While they and their children were eating, I asked the parents 4 short answer questions about their child's fidgeting habits. While speaking with the parents, I educated them on the difference between fidgeting and playing and reminded them about the group meeting scheduled for the following week.

2.4.3 Group Session

In the Group Session phase I obtained more detailed information from the parents about what fidgeting behavior and preferences they observed in their children. I met with the parents of the children in the study in small groups of 5 to 8 people

(a) Hedgehog (b) Lizard

Figure 2.3: Smart fidget prototypes shown to the children for reference.

and asked them more detailed questions about their children's fidgeting habits. The session was not a focus group in the traditional sense that a question is thrown out and the group discusses it, rather each parent was asked the same set of questions in turn with subsequent and past answers sometimes being changed upon reflection about the answers given by other parents present.

2.4.4 Brainstorming

During the Brainstorming phase, children designed their ideal fidget item complete with material and interaction preferences. This phase consisted of three activities. First, I showed the children two smart fidget prototypes (built during the work by Cottrell *et al.* [9]) and allowed them to handle and interact with them (see Figure 2.3). I explained the various interactions that were incorporated into each prototype (i.e., twisting, squeezing, petting, clicking, bending, etc) and then allowed each child to handle and interact with them. After that, I allowed the children to examine a variety of

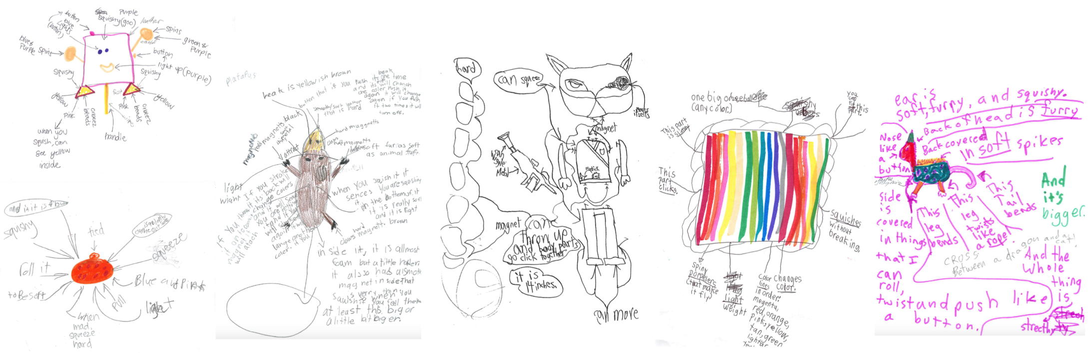


Figure 2.4: Drawings of the participants' ideal fidget items from BRAINSTORMING.

the materials the researchers considered when they developed the prototypes, so that they could have an idea some of the different materials that are possible. Finally, I asked the children to draw pictures of what their ideal fidget object would be and to label it, by asking them the following questions: If you could design the perfect fidget what would it look like? What would it be made of? What would the inside be made of? What things could you do with it? Like could you bounce it or roll it or twist it? Can you draw it for me and label the drawing with all of the materials it's made of along with all of the things that it does? When would you use it? What do you like about this perfect fidget item that you just drew? (see Figure 2.4). I encouraged them to use their imagination and incorporate any materials and/or interactions that they had been exposed to, prior to or during the study, which they would want to have in their fidget item. I then interviewed each of the children and asked them to explain their dream fidget item.

2.4.5 Teacher Interview

In the Teacher Interview phase, I obtained teacher observations regarding the children's fidgeting behaviors and preferences. The teachers were asked the same questions that the parents were asked in the Meet & Greet phase and the Group Session phase. The only difference was that the teachers were asked all of the questions one-on-one in a single session.

2.4.6 Data Handling

The video taped sessions (Exploration, Group Sessions, and Brainstorming) were transcribed. Information from the transcripts was then transferred to a spreadsheet. The spreadsheet has columns for the child associated with the fidget item, the age and gender of the child, the fidget item, whether or not the fidget item is an accessible or multi-use item, whether or not it is a complex item (has multiple interactions built in), description of the fidget item with material properties, interactions inherent in the fidget item, what the child likes about that fidget item, and when or why the child uses that fidget item. In order to obtain the preferred interactions, materials and items, I input all of the fidget items (as well as the component materials and interactions inherent in each of those items) mentioned for a particular child by either the child himself/herself, the child's parent(s), or teacher. Because I realize that a child's current fidget items might be influenced or limited by financial or parental constraints, I included information on all of the fidget items that the child identified as his/her favorites during Exploration. In addition, to make sure that the child's preferences weren't unduly limited by the fidget items that I brought to Exploration, I analyzed the ideal fidget item that each child drew during Brainstorming, recording all of its component materials and interactions. The text for each fidget item was color coded to denote the source of the information about that item with the following scheme: black - fidget items that they showed or described to me during Exploration, light blue - fidget items that I provided that they spent time interacting with during Exploration, dark blue - favorite fidget items that I provided during Exploration, green - items parents mentioned, red - items teachers mentioned, and orange - ideal fidget drawing components. I then looked to see how many children in the study gravitated towards each material, object and interaction. Analysis of the reported reasons why the children fidgeted was done in a similar way. When looking for what if any connections exist between why they fidget and what materials or interactions they chose to fidget with, I was careful to look at when they said that they used or would use a particular fidget item. I initially thought that analysis of what items the children chose to interact with during Exploration in conjunction with their favorite fidget item from Exploration might yield interesting results in terms of the child being open to various types of interactions and materials or primarily being interested in certain interactions, materials or form factors, but due to time constraints and lack of initial conclusive results I chose to ignore those items in my final analysis. Thus, the light blue items in the spreadsheet were not counted towards my final results. This makes sense as they were not items for which the child declared a preference.

2.5 Observations

During the Meet & Greet phase, I noticed that many of the parents were not clear about what I meant by fidgeting. Several of them confused fidgeting with playing and when asked to tell me about the fidgeting items that their children used, they said things like video games. I would not consider playing video games fidgeting, because it is a purposeful activity that engages a child's full attention. As a result of this, I educated the parents about what I considered fidgeting. Later, during the Group Session phase, several of the parents mentioned that after having spoken with me a week earlier in Meet & Greet, they had noticed fidgeting behaviors and patterns in their children that they had not noticed previously.

Through interacting with the teachers over the course of the study, I realized that the teachers were aware of the differences between fidgeting and playing and further, that they had a wealth of information about the children's fidgeting habits and item preferences. This seemed especially true of fidgeting behaviors done when the children were forced to sit in one place and focus on something that was difficult for them, as is the case when they study or do school work, rather being free to move about. Consequently, I decided to expand my study to include Teacher Interview to record their responses to the same questions that the parents were asked in the Meet & Greet phase and the Group Session phase.

Category	Count	Key words
Perform Cognitive Tasks	25 (89%)	thinking, working, homework, learning, school work, when they don't know the answer, reading, studying, listening, focusing, during class
Alleviate Boredom	24 (86%)	bored, boredom, bored at home, bored in class
Regulate Emotions	22 (79%)	angry, mad, sad, frustrated, anxious, nervous, calming, soothing, unhappy, upset, discomfort, chill out, scared, happy, worried
In Class	20 (71%)	school or class are specifically stated
Dispel Excess Energy	14 (50%)	excess energy, dispel energy, can't sit still

Table 2.1: The reasons why children fidget.

2.6 Results

2.6.1 Fidgeting

All of the children in my study were found to fidget. Even if one source (a parent or the child himself/herself) responded that a particular child did not fidget, I always heard from another that said child does indeed fidget along with a description of when, why and the properties inherent in the fidget items that said child uses. Further, I observed that even when a child initially responded that he/she did not fidget, that child's teacher or teacher and parent(s) responded to the contrary.

2.6.2 Why They Fidget

As can be seen in Table 2.1, there are various reasons why children fidget. I grouped the reported reasons that they were found to fidget into five categories that are not necessarily mutually exclusive. The table shows examples of the words that the study participants used to describe when/why the children fidget that were grouped into each category. For instance, thinking, learning, reading, and focusing were some of the words that I grouped into a category called Perform Cognitive Tasks. Four of the categories (Perform Cognitive Tasks, Alleviate Boredom, Regulate Emotion, Dispel Excess Energy) are location independent. By this I mean that inclusion of a stated reason in any of these four categories is based solely on the activity or desired result and not on where it occurs, while the fifth category (In Class) is defined as any fidgeting for any reason that takes place in a school or classroom type setting. I made a separate category for this location specific fidgeting because fidgeting in this setting is often discouraged by the child's parent and/or teacher. Despite this, 71% of the children still fidget in this setting. I created a separate category for fidgeting when bored rather than include boredom prompted fidgeting in the Emotion Regulation category because it was so prevalent in the data that I felt that it warranted its own category.

2.6.3 Material and Object Preferences

In my study, the results show that the children gravitated towards a variety of objects and materials when fidgeting. Table 2.2 lists the top 5 overall material/object preferences. The table is a mix of both materials and specific objects because when a specific kind of object was prevalent in the data, I felt that it warranted its own category. Otherwise, since the variety of fidget items was so diverse, I grouped items by their component materials.

Material	Count
Rubber	24 (86%)
Squeeze Ball	24 (86%)
Plastic	22 (79%)
Orbeez	17 (61%)
Pencil/Eraser	15 (54%)

Table 2.2: Materials that the participants liked.

2.6.4 Accessible or Multipurpose Item Preferences

While the children in my study fidget with a wide assortment of fidget items, many of the fidget items, especially those employed in schools or other places with classroom like settings, are accessible or multipurpose items. For this study, I define accessible as either parts of the body (e.g., hands, fingers, hair, legs), clothing, or items that are readily at hand. I define multipurpose items as those items that have a primary purpose other than as a fidget object. Items in this category include pens, pencils, erasers, white out bottles and hair ties. Twenty-six of the 28 children (93%) fidgeted with accessible or multipurpose items.

2.6.5 Soft Material Preference

From among the children's material and item preferences, I found that 20 of the 28 children in the study (71%) liked fidget items that contained a material that could be considered soft. Not to be confused with smooth or pliable, items considered soft included clothes, fur, blankets, and cotton. Several of the kids who didn't even mention cloth or fur materials did mention that they liked soft exteriors (like soft rubber).

2.6.6 Preferred Interactions

Preferred fidget interactions can be found in Table 2.3. It is important to note that I differentiated between squeeze and squish. I defined squeezing as an interaction that does not alter the original form of an object. Once squeezing ceases, the object merely returns to its original shape. Squishing, on the other hand, changes the shape of the object. You can squish clay but squeeze a stress ball. The motion involved in the two interactions is the same as both involve pressing your fingers together or closing your hand into some approximation of a fist. The difference lies in how the interaction feels to the person doing it. The push back can be of varying strengths depending on how hard it is to continue to squeeze the object in question.

When collecting data in the study, I distinguished between clicking, pressing, and tapping. For the purposes of this study, I define tapping as a motion that is done on a surface that does not change as a result of the motion. So think of tapping your fingers on a table. You move your finger/fingers in a downward motion and there is no force exerted on your finger to stop its movement downward or aid its movement back up. Clicking is similar to tapping in that you move your finger/fingers in a downward motion but unlike tapping, you must exert a force in order to move your finger in that downward motion. The object that you click is then depressed and stays that way even after you stop exerting force in a downward motion. Like tapping, there is no force exerted on your finger to aid its movement back up. Pressing is similar to both tapping and clicking in that it is done by exerting a force by your finger/fingers in a

Interactions	Count
Squeeze	25 (89%)
Click/Press/Tap	23 (82%)*
Stretch	22 (79%)
Squish	20 (71%)
Pull	19 (68%)
Roll	15 (54%)
Twist	15 (54%)

Table 2.3: Interactions that the participants liked.
*corrected from published version

downward motion. Like clicking, pressing contains a force exerted on your finger to stop its downward movement. However, unlike clicking, when you stop pressing, there is a force exerted by the object being pressed that aids your finger's movement back up. So if you pressed a button down and then stopped pressing but didn't move your finger from the button, the button would return to its original upright position the minute that you stop pressing in essence lifting your finger in the process. Due to the similar movements involved in all three, I decided to look at clicking, pressing and tapping together as one category. When considered in this way, I found that 23 of the 28 children (82%) liked objects that incorporated this interaction. Their attraction to this type of motion was further supported by the fact that 14 of the 23 children (61%) who showed a preference for this interaction built it into their ideal fidget design.

2.6.7 Relationships between materials/interactions and reasons to fidget

Regarding relationships between materials/interactions and reasons to fidget, I observed two things. First, every time a reason is mentioned for wanting to use an object that contains a clicky (pressing, clicking, tapping) interaction, the reasons given are primarily either that the child was bored or that the child was doing cognitive tasks such as focusing, doing homework, or thinking. Second, while squeezing is always a popular interaction regardless of the reason, when children are angry or stressed, they are more likely to want to interact with items that have squeeze or squish interactions built in than any other interaction. The same is not true in reverse. Just because children are squeezing or squishing a fidget object, does not mean that they are angry or stressed.

In addition to material and interaction preferences and social emotional ties to fidgeting, several other insights came out of the study related to durability, stealth and sound.

2.6.8 Rough Fidgeting

Sixty-four percent of the children in the study, 18 of the 28 participants, were observed pushing the physical boundaries of the fidget items. Many were seen to either grip the object with two hands, robustly squeezing it in an attempt to get it to burst, over-stretching to see how far they could pull one side from another, or putting all of their weight on an object while squishing it into the table.

2.6.9 Stealth

Children feel the need for stealth when fidgeting. Eight of the children (29%) mentioned in passing at some point during the study that they were worried that their fidget items would get taken away. This worry was exacerbated if the items were too big or looked "too much like a toy". The child's concern for stealth is further supported by the fact that many of the items that they fidgeted with at school were small or multipurpose items. When examining the fidget items that I supplied as part of the Exploration phase, some of the comments I overheard the children saying were: "probably not at school because I'd feel like they'll just take it away from me" and "Oh so it's too big to use either at school or at home". Of the participants in the study, 26 of the 28 children (93%), reported using accessible (e.g., body parts, hair, clothing) or multipurpose items (e.g., pencils, erasers, hair ties, white out bottles) that couldn't be taken away.

2.6.10 Sound

Children like sound. Eleven of the 28 children (39%) mentioned liking an object because of the sound that it made. An example of this is that one child liked clicking the buttons on the light switch side of the fidget cube stating 'I really like this clicking noise'. However, as was the case with fidget items looking too much like toys, children were careful not to choose items that were too loud. Among them, several liked the slight squishing sound that a gel filled squeeze ball made when it was squeezed. One of these children stated that 'if you put it up to your ear it sounds like it's really- it sounds like it's really squishy.'

2.6.11 Fidget Item Form

The children in my study were found to fidget with both creature-like and abstract fidget items, with creature-like items being among the fidget items of 19 of the 28 children (68%). Creature-like items refer to any item that has a face and could be anthropomorphized. 10 of the 25 children (40%) who completed ideal fidget designs in the Brainstorming phase created creature-like designs.

2.6.12 Parent Responses

I was able to obtain fidgeting behavior and preference information concerning 27 of the children in the study from the 24 parents who participated. This was due to some siblings being in the study. Of these 24 parents, 18 participated in both the Meet & Greet and the Group Session providing information concerning 21 of the children. Of the 18 parents who took part in both the Meet & Greet and the Group Session phases (though asked similar fidgeting related questions in the two phases), 12 parents (66%) gave much more detailed information regarding their child's fidgeting behaviors and fidget item preferences in the Group Session phase as opposed to the Meet & Greet. Of those 18, three specifically mentioned they were able to give more informed answers as a direct result of participating in the Meet & Greet phase.

2.6.13 Teacher Responses

My analysis of the collected data supported my decision to expand out study from four phases to five with the inclusion of the Teacher Interview phase. The teachers gave more detailed responses in 14 out of the 20 cases where the information was obtained from both the parent(s) and teacher. In addition, teachers were often more cognizant of when and why the children fidgeted as opposed to just that they did. Further, while parents' fidgeting answers were often vague, especially when asked if they noticed any patterns to when or why the children fidgeted, teachers could often find social and emotional tie-ins as to why they were fidgeting. For instance, the teachers were more likely to link the fidgeting to a particular activity or state of mind and were better able to explain how fidgeting with that item served the child. An example of this is that while one parent was unable to cite any reasons connected to their child's fidgeting, her teacher stated that the child fidgeted to "calm and center her, and it makes her happy". Another example of this is that even though both a parent and a teacher referenced a child fidgeting with a ball, the parent stated that the child fidgeted with it when bored while the teacher said that he used it when "he's angry or needs to take a time out...I don't know if it's a control thing", it's self soothing and a mode for him to focus.

2.7 Discussion

2.7.1 Conclusive findings and links

The Meet & Greet phase of the study was designed for two purposes: to obtain preliminary data about the children's fidgeting item preferences and habits and to get parental buy-in of the study to encourage their participation in the Group Session phase. However, during the Meet & Greet phase, I noticed that many of the parents were unaware of their children's fidgeting habits and preferences and in fact, in some cases, even of the difference between fidgeting and playing in general. This is suggestive of two additional benefits of the Meet & Greet phase of the study. First, by reminding the parents of the Group Session phase the next week and telling them that I would be asking more detailed questions about their children's fidgeting habits and item preferences at that time, I was able to focus their attention on this activity for the next week. Second, the phase provided an opportunity for me to educate the parents on the difference between fidgeting and playing and thereby ensure that their attention was focused towards the correct activity. Therefore, the main functions of the Meet & Greet phase were to educate the parents, obtain study buy-in, and focus attention on fidgeting activity.

Several of the parents mentioned during the Group Session that after having spoken with me a week earlier during the Meet & Greet, they had noticed fidgeting behaviors and patterns in their children that they had not noticed previously. The children's fidgeting habits did not change as a result of the Meet & Greet, but rather the parent's knowledge and awareness of fidgeting was raised due to their participation in the Meet & Greet.

As initially designed, my study was a four-phase study devoid of the Teacher Interview phase. However, through interacting with the teachers over the course of the study, it became clear that they were often more attuned than parents to the children's fidgeting behaviors and preferences. This seemed especially true of fidgeting behaviors done when the children were forced to sit in one place and focus on something that was difficult for them, as is the case when they study or do school work, rather being free to move about. Consequently, I decided to expand my study to include teachers' responses to the same questions that the parents were asked in the Meet & Greet phase and the Group Session phase.

Since the teachers were not only involved in the planning of the sessions but also had to be present in the room during each session that involved the children, they were already aware of the differences between play and fidgeting and their attention was already focused on those behaviors. Further, since teacher buy-in was essential in order to conduct the study in their classrooms it was obtained prior to the study. As stated previously, the primary functions of the Meet & Greet were to obtain buy-in to encourage participation in the Group Session, to educate on the differences between play and fidgeting, and to focus their attention on the children's fidgeting. Therefore, since the main functions of the Meet & Greet were already obtained with regards to the teachers, I decided to combine the two parent phases (Meet & Greet and Group Sessions) into one phase for the teachers. Consequently, the teachers were asked in one session all of the same questions that the parents were asked in the two. Analysis of the information obtained from the teachers substantiated my decision to include the teachers and combine the two phases into one for the teachers. Further, as suspected, their answers alluded to the teachers often being more aware of fidgeting that takes place when a child is bored or forced to sit in one place or work on school related cognitive tasks such as homework, learning something new, focusing, and reading.

Analysis of the data leads me to believe that the contrasting participant (parent, teacher and the child him/herself) observations regarding whether or not a child fidgets or in what situations a child tends to fidget stem not from the child him/herself rarely or sporadically fidgeting but rather from the responder not noticing it or not being around in situations where that particular fidgeting behavior is done. That a child would respond in the negative when asked whether or not they fidget and their parent(s) and teacher would respond that they did, merely underscores the thought that fidgeting is often a subconscious act rather than a conscious one. Given that several of the parents in the study held more than one job or juggled school and work, it is not unlikely that a parent would fail to notice all of their child's fidgeting given the many demands on their time and focus. In addition, many of the children finished their homework at the after school program so their parents seldom if ever witnessed them focusing on schoolwork or any fidgeting that might accompany that activity. It is important to note that the teachers interviewed never responded that a child did not fidget. I think this is because the teachers spend the majority of their time with the children in a classroom-like setting where they are watching the children while supervising their behavior and work.

I was initially concerned that showing the prototypes to the children prior to having them design their own ideal fidget item would unduly influence their designs. In order to offset this, I told them that the prototypes were a combination of all of the interactions and materials that the people who made them thought should be included in an ideal fidget item and that they (the children) should think of all of the fidget items that they already used and that I had shown them during the course of the study, in addition to the materials that I shared with them in the beginning of the session, and imagine a perfect fidget item that incorporated the materials and interactions that they liked the best. As a result of this, the drawings that the children made do not seem to have been influenced by the prototypes. The ideal fidget item drawings ranged from very complex items with multiple interactions built in to simple items with only one interaction. With the exception of maybe one dragon/cat fidget item, which is only similar to the lizard prototype in that dragons are somewhat similar to lizards, none of them looked at all similar to the hedgehog or the lizard prototypes.

The results showed that the majority of the children exhibited a tendency to test the physical limitations of a fidget item by interacting with it in a rough manner. Due to the prevalence of rough fidgeting behavior observed by the children, durability is a main concern when making or choosing fidget items for children. Perhaps the children's propensity toward what I deem as rough interactions can be attributed to their natural curiosity with regards to how things are made and what they can do. One exchange with a child during the Exploration phase that was indicative of this was as follows:

CHILD: like this one I like because, this one (blue to green squish ball with the net) it makes you want to cut it but then at the same time it doesn't want you. Like you wanna cut it but you don't want to cut it

RESEARCHER: cut it meaning get rid of the bag?

CHILD: no

RESEARCHER: cut it meaning you wanna get what's inside out?

CHILD: yeah, like (motions cutting the part sticking out of netting with finger)

Unlike adults, children must satisfy their fidgeting urges while operating within parental or teacher parameters of what is acceptable. From my observations of and interviews with the children in the study, I discovered that what they choose to fidget with is impacted by the environment in which they are fidgeting and whether or not they have to satisfy their fidgeting needs within the confines of what their parent(s) and/or teacher(s) find appropriate. Due to this adult imposed constraint, children often forgo their preferred fidget items and instead try to make-do with something that they think they can get away with. As a result of this many children choose to fidget with accessible or multipurpose fidget items that are much less likely to be taken away by parents, teachers, and/or caregivers. This is further evidenced by the fact that children try to accommodate their desire for fidgets that make noise by choosing fidget items that make subtle sounds that are less likely to be heard by anyone else. An example of this is the barely discernible squishing sound that a gel filled squeeze ball makes when squeezed.

In line with my results concerning children's need for stealth, they are very conscious of the size and conspicuous nature of things and of what they think they can get away with in different locations. One child chose a favorite fidget item in the Exploration phase and when asked where she would interact with it she said that she would interact with it at the after-school facility. When asked if she would also interact with it at home or at school, she replied 'no because it's too big.' She went on talk about another of her preferred fidget items and said that she liked it 'cuz it was more compact.'

Kids were found to value tactile sensation as the majority of children stated a preference for fidget items made of soft materials.

In a way, squeezing is similar to pressing in that both actions require force to move or change the shape of the object and both also experience a push back sensation as the object tries to return to its original shape or position. Similarly, squishing is much like clicking in that though force is required to click or squish the object, the object stays in the position that those actions put it in and there is no push back. So given the similarities between these preferred interactions, it is interesting that squeezing and pressing are not the preferred interactions for one emotion or activity and squishing and clicking are not the preferred interactions for another. All four interactions use movement of the fingers and yet the sensations they create are different. Perhaps it is because squishing and squeezing results in a clenched fist which goes better with dispelling energy when you are angry and pressing and clicking do not.

2.7.2 Use-Case scenarios

Future studies with children on the benefits or disadvantages of fidgeting should include fidget items that appeal to the largest subset of children. My findings of the most popular fidget interactions and material properties can be used to inform the selection of fidget items to use in these studies. By incorporating fidget items with characteristics that appeal to a broader range of children, children are more likely to fidget with them organically rather than having to be prompted. Therefore, selecting fidget items with squeeze, squish, press, click, tap and stretch interactions and soft rubbery materials might yield more accurate results than incorporating fidget items that children do not naturally want to interact with.

Since children gravitate toward fidget items that make sound but fear of having them taken away prevents the children from either choosing them or else from using them in school and/or home settings, fidget items with either subtle sounds or sounds that can be turned off should be created or used during fidget studies. These fidget items would still satisfy their desire for noise while also making the items less distracting to those around so they will be less likely to be taken away. This will enable the children to use them in a multitude of settings that should yield better results in long term studies where the children take the fidget items home.

Further study is suggested to determine if my initial findings that a unidirectional link between anger and a preference for fidget items with a squeeze interaction exists for all or the majority of children. In addition, because my findings show that children have a propensity to gravitate toward fidget items with a squeeze interaction when angry, future studies regarding whether or not fidgeting can serve to aid in self regulation by diminishing anger might yield more accurate results by incorporating fidget items that have an inherent squeeze interaction than by using fidget items without this interaction.

My findings also showed a link between the fidget actions of pressing, clicking, and tapping and performing cognitive tasks such as studying, doing homework, focusing, and learning. I suggest that future studies be conducted exploring this relationship to determine whether or not it holds true with other populations of children or even other populations in general. Additionally, studies interested in whether or not fidgeting aids cognitive functions such as focus, retention, or understanding could benefit from the inclusion of fidget items with inherent pressing, clicking, and/or tapping interactions. Further, since I also found a link between boredom and fidget items with those inherent interactions, studies regarding whether fidgeting could modulate boredom could potentially increase their accuracy by incorporating such items.

2.8 Conclusion

I conducted a five-phase field study which focused on the fidgeting habits and fidget item preferences of children between the ages of 6 and 11, for the purposes of discovering when and why they fidget, in addition to what types of fidget items they naturally gravitate towards in terms of their material properties (exterior and interior materials) and interactions.

My findings revealed that the children in my study fidget for a variety of reasons: engaging in cognitive tasks, regulating emotion, and dispelling excess energy. Of the emotions that tend to trigger a need to fidget, boredom was the most prevalent. Top material preferences for fidget items were rubber and plastic while top fidget objects were squeeze balls, Orbeez, and pencils/erasers. Squeeze, stretch, squish and the combined category of click/press/tap were the four most liked interactions inherent in fidget items. Further, I found that stealth, durability and sound are all things that need to be considered when building fidget items.

Children are forced to satisfy their fidgeting needs within the narrow confines of what they think the adults will let them get away with using. Therefore, if a fidget item is intended to be used all the time, in order for it to be used and evaluated successfully, either the issue needs to be addressed with both the parents and the teachers of a child by educating them on the possible positive outcomes of fidgeting and fidget items or else the fidget items developed need to blend into the child's usual environment either by being or looking like multipurpose items.

I believe the results of my study are of value to anyone interested in creating tangible interfaces for children, who would like to be sensitive to the affordances of the materials and potential manipulations of those tangibles. My own research group is currently using the results of this study to engage in the development of smart fidget objects to aid children in self-regulation and emotional management.

Chapter 3

Fidgetato: Developing A Research-Grounded Fidget Tracking Object

3.1 Introduction

Research in the area of fidgeting and fidget-friendly tangibles has increased dramatically in recent years [8, 10, 18, 23, 24, 26, 27, 33, 36, 38, 40, 41, 45] as products that encourage fidgeting have become more commonplace in society. While fidgeting as an observed behavior is not new, products claiming to increase focus and concentration or self-regulation through fidgeting are [42]. This plethora of products has heightened interest from parents and educators in whether or not fidgeting is beneficial or detrimental and, by extension, whether they should encourage or discourage that behavior.

Despite this heightened interest, researchers have yet to reach a consensus regarding the costs and benefits of fidgeting [36]. Many perceive fidgeting as indicative of a lack of interest or attention [7] and this negative perception of fidgeting is so pervasive that there are even some studies that are based on this assumption [14]. However, some studies have found evidence that there are various benefits derived from fidgeting [4, 33, 41]. In one study, children found fidgeting beneficial when trying to come up with the optimal wording for an answer to a problem [35]. Other studies have postulated that fidgeting may help regulate focus [8, 12, 31, 38] and possibly increase information retention [4].

Research studies attempting to delve into the costs and benefits of fidgeting often use fly-on-the-wall observation techniques or questionnaires and readily available fidget items [33, 38, 41]. As research in this area increases, an interest in capturing more accurate real time data collection has emerged; data that would be impossible to capture using fly-on-the-wall or video capture studies. In a study that was unable to identify any benefits from fidgeting [23], Kaabi et al. noted that their research would benefit from more accurate measuring of fidgeting behavior.

Concrete data collection during testing which traces fidgeting interactions would not only indicate when people fidget but also how they fidget. More accurate data streams would lend themselves to computer-based analysis methods such as machine learning. This more fine grained analysis could lead to insights about previously identified relationships [10] between when and why someone fidgets (emotions or activities engaged in) and how they fidget in terms of rate and types of interaction (pressing, rolling, etc.).

To fill this need, my research focused on designing and constructing a fidget tracking object to be used as a tool for research into fidgeting behaviors. In this chapter, I describe the design of the object and findings from a preliminary study of how it was received.

3.2 Related Work

As mentioned in the introduction, fidgeting research has increased in recent years, with some studies seeing possible benefits derived from fidgeting [41]. Conversely, other studies found no associated benefits to fidgeting with respect to focus and retention [40].

Even though researchers have not come to a consensus about the value (or lack of value) of fidgeting, one research team at Florida Atlantic University developed a prototype that alerts the wearer to fidgeting actions. Thus giving the wearer the possibility to curtail their actions [5]. Recognizing the negative connotations that exist regarding fidgeting and yet acknowledging people's need to fidget, researchers at Eindhoven University of Technology chose to create jeans that enable rather than discourage fidgeting by incorporating large pockets with built-in fidget objects into their design so that the fidgeter my fidget discretely [21].

Researchers at the University of Bergen created a small object [18] that records squeezing as a way to facilitate communication between a dentist and patient during dental procedures. This object, while not created for fidgeting studies, does contain one of the interactions that my previous children's study (see Chapter 2) identified as having a strong relationship with self-regulation and could lend itself to studies of this type.

A limited but growing body of research regarding fidget object creation exists. Karlesky and Isbister [24, 26, 27] created fidget objects called Fidget Widgets which were to be used while working at a computer. These fidget objects were designed to "selectively modulate affect and shape cognitive state to support a user's productivity and creativity". Work at Nottingham Trent University involved the creation of an "iFidgetCube" [45] to study fidgeting behaviors and provide both fidgeting interactions for self-regulation as well as tracking data to infer well-being.

The primary distinction between the prior work concerning fidget tracking objects and my current research is that I based my design on my previous research which identified fidgeting interaction preferences (see Chapter 2). I incorporated affordances that would lend themselves to the study of both (a) self-regulation and boredom and (b) focus and retention. By leaning on insights from previous studies, I hope to have created a fidget tracking object that will be suitable for a broad range of studies and may support people with different fidget preferences in a wider range of contexts.

3.3 Fidget Object Creation

3.3.1 Design Criteria

Prior to starting the actual design of the object, I spent time envisioning the types of questions that I would like studies with the device to be able to answer, and by extension, the types of studies for which I would like it to be suited. This resulted in the identification of the following essential properties I wanted the self tracking fidget object to have: portable, comfortable, ambidextrous, and attractive.

Portable:

I thought about Karlesky's work on Fidget Widgets [24, 26] and how they were specifically created to provide insight into the space that he termed the "physical margin spaces around software". I also noticed upon reviewing the submissions to Karlesky's Fidget Tumblr [27] that while the characteristics of the objects submitted vary widely, the objects could be split into two main groups by determining if they were easily portable or not. The questions I am interested in being able to explore extend beyond the bounds of Karlesky's defined space. I am interested in obtaining insights into fidgeting patterns and potential benefits and/or costs throughout the day in various work and non-work settings. Therefore, the smart fidget object created could not be a desktop object but rather needed to be easily portable, making portability my first design parameter.

Comfortable:

Since I already knew I wanted the fidget object to lend itself to longer term studies where participants would need to carry and interact with the fidget object over the course of a day or several days, it was important for the fidget object that we created to be comfortable to hold and interact with. Participants would not want to interact with it if they found the object to be uncomfortable. So designing an object that was comfortable became my second main design consideration.

Ambidextrous:

I wanted the fidget object to be equally usable by both left-handed and right-handed people for several reasons. First and most importantly, I wanted the fidget object to be accessible for as many people as possible. Second, I did not want to have to pre-screen participants and then exclude one group or the other for testing. Finally, I did not want, nor did I want anyone who used the smart fidget object for fidgeting research, to have to account for the possibility that fidget preferences, benefits, or costs vary depending on whether or not someone was left-handed or right-handed and be unable to test both groups to confirm or negate that supposition.

Attractive:

I define “attractive” to mean the property of an object that makes people want to pick it up and interact with it. With that definition in mind, it is important that our fidget object be not only comfortable and portable but also that people gravitate towards it due to the way it looks and feels and the affordances it provides.

Once I identified the essential properties, I used them to guide the design of the smart fidget object. I divided my design into three interdependent parts: tracked affordances, external casing, and internal mechanisms.

3.3.1.1 Tracked Affordances:

Early in my design process, I looked for research that would guide me concerning which interactions to include in the smart fidget object, and was unable to find any research that delved into adult fidget interaction preferences. Karlesky's Fidget Tumbler [27] contains a wide variety of preferred fidget items, but no formal work has yet been done that recommends which affordances appeal to the largest number of adults. I did however have my prior research on children's fidgeting preferences (see Chapter 2). Rather than duplicate that study with adult participants, I decided to lean on its results to aid me in the design of the smart fidget object, with the thought that it was possible that some or all of the preferences people have as children might extend into adulthood. Then I can use that object to gain insight into whether or not children's preferred interactions appeal to adults.

As identified by my prior children's study (see Chapter 2), the most popular interactions for children are shown in Table 2.3. Not only are there a variety of interactions listed, but there is no one individual interaction that everyone, or at least every child, prefers. From that list of interactions, I decided to include affordances for squeezing, clicking, and pressing, as those interactions were identified in the same paper as not only being well liked, but also to have a relationship with certain activities and mental/emotional states. The children's study found a unidirectional relationship between anger and a preference for squeezing, and a bi-directional relationship between pressing and clicking and both boredom and engaging in cognitive activities like study-

Figure 3.1: Hand-hold Test Samples

ing, working, and thinking. By including these interactions, I thought that the smart fidget object could be used to investigate whether or not those same relationships exist with the majority of adult fidgeters.

3.3.1.2 External Casing:

Prior to designing the external casing, I looked for inspiration for the size and shape I wanted by examining fidget and everyday objects and then conducting hand-hold tests for size and comfort. I wanted the object to be as big as possible to hold the internal components, while remaining comfortable and easy to handle. This exploration yielded the object shown in Figure 3.2 as a rough guide for the ideal size and shape of the fidget object. Examples of some of the objects used in the hand-hold tests can be seen in Figure 3.1.

(a) Front View (b) Side View

Figure 3.2: Rough Guide for the Ideal Size and Shape of the Fidget Object

3.3.1.3 Internal Mechanisms:

One of the properties that I considered essential for my design was that the fidget object was portable. This portability requirement impacted my design by necessitating that it could function without being tethered in any way to either an external battery source or a data storage device. In addition, since I wanted the object to lend itself to short term longitudinal studies, I realized that the battery and data storage components should have sufficient capacity for at least one full day, preferably several days, so that study participants for longer term studies would not need to recharge it or upload the data each night.

3.3.2 Design and Development Choices

3.3.2.1 Tracked Affordances:

I realize our fidget object (Roger Conatser built the actual prototype according to my design criteria and design and development choices) provides a multitude of

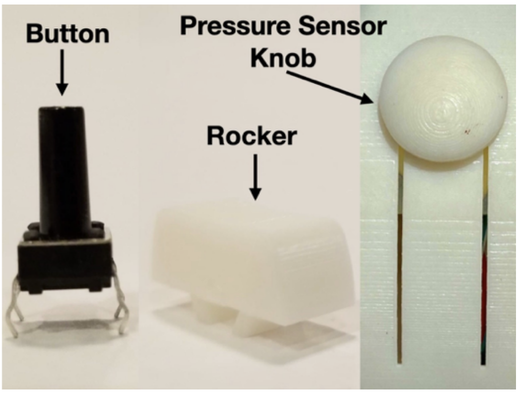


Figure 3.3: Fidgeting Tracking Components

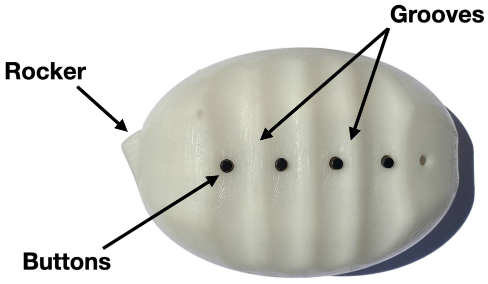
affordances many of which I never thought of nor intended. It can be thrown or used as a paperweight for instance. I make the distinction that the following tracked affordances were designed into the smart fidget object in such a way that would enable me to know when participants used those affordances.

Pressing

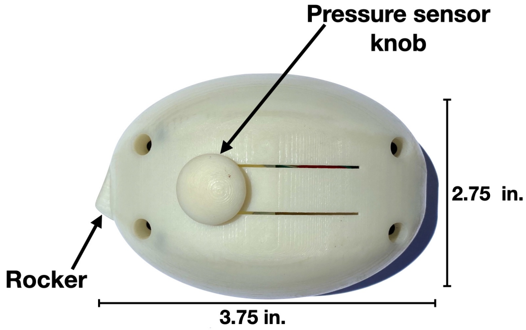
The fidget object provides the pressing interaction through four black buttons that can be pressed (see Figure 3.3). These buttons return to their starting position once force is removed, and make slight clicking sounds both as they are depressed and as they return to their fully extended starting position.

Clicking

The fidget object has a "light switch"-like component that provides a clicking interaction which I will refer to as a rocker. Once one side of the rocker is clicked, it stays in that position until force is applied to the other side. Rather than looking for some kind of switch of this type, we chose to design and print our own (see Figure 3.3). Similar to the buttons, the rocker makes a slight clicking sound when clicked.



(a) Front View



(b) Back View

Figure 3.4: Fidgetato

Squeezing

In order to track when people squeezed the fidget object, we designed a knob-like protrusion into the exterior casing (see Figure 3.3). When the fidget object is squeezed, pressure is applied to this knob and it is slightly pushed into the fidget against a load cell which measures how hard the person is squeezing.

3.3.2.2 External Casing:

The final prototype can be seen in Figure 3.4. I refer to it as the Fidgetato as it resembles a potato and the potato based pasta gnocchi. It is oval in shape with an overall length of 3.75 inches, width of 2.75 inches, and thickness of 2.25 inches. Buttons were arranged in a horizontal line down the front of the fidget so that each finger could press a different button (see black buttons in Figure 3.4a). Grooves were incorporated into the front side of the fidget with each groove containing a button. This was done to make it easier for people to orient the fidget in their hands without looking, so that their fingers align with the buttons and the pressure sensor rests against the palm. The

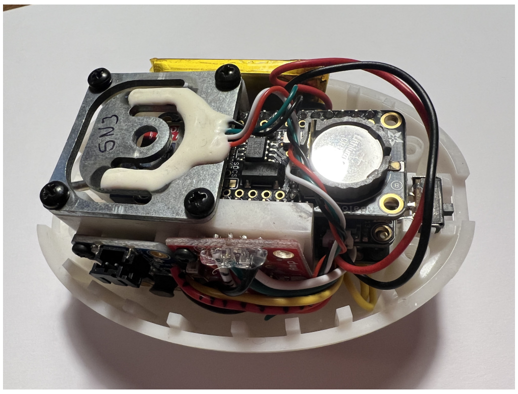


Figure 3.5: Internal Mechanisms of the Fidgetato

rocker was situated at the top of the fidget (see triangular protrusion on left side of Figures 3.4a and 3.4b) so that the thumb could interact with it while holding the fidget with fingers in the grooves. The pressure sensor knob was situated in the back of the Fidgetato so that it rests against the fatty part of the palm below the thumb (see Figure 3.4b).

3.3.2.3 Internal mechanisms:

Due to the external size limitations, the internal components needed to be arranged in a compact fashion (Figure 3.5), limiting the choice of what components we could use. Reducing the overall size of the Fidgetato further would necessitate having custom boards and components made.

Due to my portability requirement, we chose to incorporate a 150mAh Lithium Ion battery which is sufficient to provide at least a full day of data collection without charging. We also included an 8 GB micro SD card which will provide ample storage for long-term data collection. A power relay was added to enable auto shutdown.

Datatime	Unixtime	ms	Rocker	B1	B2	B3	B4	ButtonByte	lbs
18:55:43	1636829743	3746	1	1	1	1	1	11111	0.0
18:56:01	1636829761	21744	1	1	1	1	1	1111	0.7
18:56:01	1636829761	21846	1	1	1	1	1	1111	1.4
18:56:01	1636829761	21897	1	0	1	1	1	1011	1.5
18:56:01	1636829761	22128	1	1	1	1	1	11111	0.9
18:56:05	1636829765	26171	0	1	1	1	1	11111	0.1
18:56:09	1636829769	30060	1	1	1	1	1	11111	0.1

Table 3.1: Sample of Data Output

In order to track how hard the *Fidgetato* is being squeezed at a given time, we used a full bridge strain gauge load cell to minimize error due to temperature drift. A real time clock was also included to align fidget inputs to timestamps. This will enable future studies to collect granular data on how users' fidget behaviors change over the course of different activities.

3.3.3 Data output:

Temporal fidget input data are recorded in text files. A toggle button on the device allows the user to create a new text file, allowing data samples to be easily split into intervals. A data sample is recorded whenever the state of the rocker or one of the buttons is changed, or when the load cell value (which determines the amount of pressure exerted) changes by an amount in excess of signal noise.

Table 3.1 shows an example of the device's data output. The Datetime, Unixtime, and ms (milliseconds) columns record timestamp information. The Rocker, and B1-B4 columns represent the current state of the rocker and buttons, and the lbs column tracks the current pressure exerted on the object in pounds per square inch. The ButtonByte column redundantly stores button states to allow for error-checking.

3.3.4 Fine-tuning Usability:

Beyond the typical troubleshooting during initial development that made the device generally functional, additional work was done to ensure adequate data collection rate and data file integrity.

Trial testing by the research team uncovered that there were missing data points when the buttons were pressed and released very quickly making it possible to "out fidget" the fidget objects ability to capture and record data. To increase the data collection rates, a millisecond timer was added and the clock rates of both the load cell signal processor and the digital port expander were increased. This modification increased data capture from 2 to 3 samples per second to at least 10 samples per second.

In order to address concerns about data file integrity if the fidget object were to lose power during testing, the ability to monitor battery voltage and close the current file prior to shutting down was added. The components necessary to implement this change also enabled a battery saver feature which shuts off the fidget object if it has not been used for a given period of time.

In addition to the above mentioned modifications, several programmatic changes were implemented that affect things like how long the fidget object will stay on after the last interaction before powering down and when the light (see Figure 3.4a for location of light) will turn on or flash. These code changes did not substantially alter the

(a) Left to Right: *Fidgetato*, P5, P7, P9 and P1

(b) Left to Right: *Fidgetato*, P2, P6, and P10

Figure 3.6: Clay Models from User Testing

functioning of the fidget object but will make working with it easier.

3.4 Fidget Object Preliminary User Testing

Once the fidget object was completed, I ran a small study to see if the *Fidgetato* was a viable fidget object people would interact with. This was not a formal test to gain insights into fidgeting behaviors, but rather an informal interview in order to get feedback on the fidget object itself. As both my children's study (see Chapter 2) and Karlesky's Fidget Tumbler [27] show, fidgeting interaction preferences vary widely. I did not anticipate that we would create everyone's perfect fidget or even one person's perfect fidget. What I was aiming to create was a fidget object that afforded at least one interaction that people gravitated toward and could interact with.

3.4.1 Method

My study had 11 participants: three women and eight men. For the test, I handed each participant the *Fidgetato* and asked them to hold it and interact with it for at least half an hour. During that time, they were free to do other things or sit and chat. Then I asked them to give feedback on the *Fidgetato*. Each participant was asked to tell me what they liked and what they didn't like. In addition, because I noticed during the interaction time that the first participant was pulling and trying to slide the pressure sensor knob, neither of which it can physically do, I specifically asked them to tell me if anything was confusing or if they weren't sure how something worked. Their feedback was video taped.

After providing feedback, each person was given some modeling clay and asked to make a model of what they would like a second iteration of the fidget object to look like. They were encouraged to take as much or as little clay as they needed to make it the size and shape that they would prefer, along with including any interactions that they wanted included. Afterwards, I asked them to explain their model to avoid any confusion on my part as to what affordances they wanted the various models (Figures 3.6 and 3.7) to provide and what design elements were intended versus created merely as a side effect of their lack of expertise creating clay models. For instance, if some of the participants left components out or changed their size merely because they were going for an idea rather than an exact replica of what they wanted. Their explanation of their model was also video taped.

(a) Left to Right: *Fidgetato*, P8, and P11

(b) Left to Right: *Fidgetato* and P4

Figure 3.7: Additional Clay Models from User Testing

Participant three's clay model varied greatly from the *Fidgetato* and could in no way be considered a second iteration on that general idea. The model created was of a one inch green square (not pictured) that did not have any interactions. This was especially surprising considering that Participant 3 had mentioned liking several aspects of the *Fidgetato* during the feedback session immediately preceding making the clay model. After this happened, I made sure to explain more fully to later participants that I wanted them to make a clay model of what they would like a second iteration of the smart fidget object to look like. It is possible that there was a language disconnect as Participant 3's native language is not English.

Each participant was tested separately so that their answers and how they chose to interact with the fidget object would not be influenced by the other participants.

3.4.2 Results

The results of the user test cover feedback on both the tracked affordances and the external casing, in addition to providing comments about how much they liked the *Fidgetato* overall, and offering suggestions about how to make it better.

3.4.2.1 Tracked Affordances:

Pressing

Ninety-one percent of the participants chose to include buttons in their clay model with fifty percent of them stating that they liked the buttons the best, and commenting about how satisfying they found interacting with them. Two specifically mentioned really liking the sound that the buttons make when pressed. Three participants used their thumbs to press the buttons rather than their fingers.

Clicking

Sixty-four percent of the participants chose to include one or more rockers in their clay model, with six of them liking it the best of the tracked interactions. One participant, Participant 11, stated that the rocker was perfect because *"naturally that's my fidget style with this kind of switch"*. Three mentioned that they liked the sound that the rocker makes with one, Participant 7, mentioning that she found the sound relaxing. Participant 7 liked the rocker so much that she added an additional rocker at the bottom of her clay model so that she could click either the top one with her thumb or the bottom one with her pinkie finger. Three participants used their forefingers to click the rocker rather than their thumb.

Squeezing

All eleven of the participants were confused by the pressure sensor knob at the back of the fidget object (see Figure 5.1b) unsure what it was for and how to interact with it. Many were frustrated or worried that they would break it. All tried sliding or pulling the knob. Once the feedback session was over, I explained the purpose and function of the pressure sensor knob and then sixty-four percent of the participants liked the idea of being able to track how often and how hard they squeeze things throughout the day and then chose to include one or a modified one in their clay model. After hearing about its purpose, participant 11 stated *"the fact that it is a pressure sensor is great because any position that I hold it in, I press on it"*. The biggest departure from the original design came from participant 7 who thought having a button on the front pressed with the ring finger and another on the back that pressed into the fatty part of the palm below the thumb would work better and would be more comfortable. (See white button on Participant 7's model in Figure 3.6a)

3.4.2.2 External Casing:

Size

Ten of the participants commented about the overall size of the object, with eight wanting one or more aspects (length, width, thickness) of the *Fidgetato* altered to better fit their hand, and two mentioning that they liked the size. Their comments were reflected in their clay model designs, where four of the participants made models that were smaller in all three dimensions (see Figure 3.6a), three made models that were smaller in two (width and thickness)(see Figure 3.6b), and two made models that were smaller in one (thickness) (see Figure 3.7a). One participant, Participant 4, said *"I like the size of it with respect to my hand. It feels very substantial."* He then made a model that was slightly larger in both length and width (see Figure 3.7b). Of interest was that even though Participant 2 stated that he *"liked the general size and shape for my hand"*, he subsequently created a model that was substantially thinner and narrower than the *Fidgetato.* (see Figure 3.6b). When asked about the discrepancy between his feedback and his model, Participant 2 stated that having to manipulate more clay to make a model of the same size as the original was a factor in his making a somewhat narrower and thinner one.

Shape

Six of the participants commented about the shape, either liking it or thinking that it would work for the interactions provided. This was reflected in the clay models as many had shapes similar to the original.

Grooves

Four of the participants really liked the grooves, with Participant 1 adding grooves on the side of his clay model so that he could interact with them even when not wanting to press the buttons. The main feedback about the grooves was that if they fit your fingers, the fidget object was a bit big, and if they were too small for your fingers, then the fidget object fit fine. Participant 2 commented that the location of the grooves in relation to the buttons made interacting with the buttons *"a little tricky, I mean they are not tricky to press..it doesn't take that much force but like with the posture that's* *implied by the finger grooves, it's like not a lot of leverage to press the buttons"*.

3.4.2.3 Overall Feedback

Five of the participants specifically mentioned that they liked the *Fidgetato* as a whole, using wording such as: *"it's really cool"*, *"tantalizing"*, and *"it works well"*. Only one participant mentioned that he didn't really care for it using the wording: *boring, not comfortable,* and *not enjoy holding it.*

Several participants mentioned that they thought that the *Fidgetato* was cute, because the pressure sensor knob made the back of the *Fidgetato* look like a face.

3.4.2.4 User Suggested Additions and Material Changes

Three participants mentioned that they would like it more if it had a squishy exterior. A forth participant, Participant 5, mentioned changing the exterior material in connection to squeezing and the pressure sensor, stating that the pressure sensor was unlikely to record any squeezing interactions from her, because she is unlikely to squeeze a hard plastic object that didn't give when squeezed. She thought that she would be more likely to squeeze the *Fidgetato* if it was squishy and would give when squeezed.

Several participants chose to add additional components on their clay models, with two adding a joystick and two adding a scroll wheel. Participant 11 wanted an affordance for spinning built in and stated that if it was made thinner, then he could spin the F*Fidgetato*, which was an interaction that he enjoyed doing with his cell phone and did frequently.

Three participants mentioned wanting larger and maybe softer buttons. One participant stated that she didn't think that she would squeeze the *Fidgetato* because it had a hard shell so she didn't need the pressure sensor, but that she probably would squeeze it if it had a squishy exterior.

3.4.3 Discussion of User Testing Results

As I discussed earlier, I wanted to make an electronic fidget object for adults with the capability to track interactions. No research has been done to date exploring adult fidget object interaction preferences so I leaned on my prior research with children which identified preferred interactions and relationships between a couple of preferred interactions and cognitively demanding activities. Informed by this work, I designed and created a device with a suite of tracked affordances. I believed basing the choice of provided affordances on prior research would result in a device that would be appealing and usable for a majority of people as a fidget object. In this section, I present some general insights about how people engaged with the object's design.

Size

The major takeaway from this preliminary test was that all of the participants could engage with one or more of the interactions provided by the *Fidgetato* in a satisfying way. Three of the participants adapted how they held the *Fidgetato* to compensate for its size relative to their hands, which resulted with them interacting with it in a way slightly different from the majority of the participants (I.e. pressing the buttons with their thumb and the rocker with their fingers) but that accommodation didn't prevent them from engaging in the interaction. Since my objective in creating the *Fidgetato* was not to force people to use or hold it in any particular way but rather to create an object that they wanted to interact with, I was not concerned that they found ways to interact with it that I had not thought of ourselves. Therefore, the size of the *Fidgetato* relative to each participant's hand in no way deterred them from interacting with it.

Pressure Sensor

While all of the participants found the design of the pressure sensor confusing when given the *Fidgetato* without any operating instructions, after being told what the pressure sensor was for, many liked the idea of being able to track how and when they squeezed the object and chose to include it or a version of it in their clay model.

Sound

Five participants specifically mentioned sound during their feedback - two liked the sound that the buttons made, two liked the sound that the rocker makes, and one, Participant 7, liked the rocker sound but disliked the button sound. My prior children's study (see Chapter 2) found that children liked sound but that they worried about having fidget items with sound because they were more likely to get taken away. It appears that adults do not have the same concerns as only one participant, Participant 6, mentioned that he usually avoided interacting with things that made any sound.

It's interesting that Participant 7 loved the rocker clicking sound so much that she found it *"relaxing"* and hated the button clicking sound so much that she said that it would make her nervous. So evidently for some, sound is not bad in and of itself but rather the type of sound.

Grooves

The grooves were intended to help orient the Fidgetato to interact with the buttons without having to look at it. For the most part the participants liked the grooves as nine of the participants chose to include grooves in their clay models. Two of the nine (Participants 1 and 4) specifically mentioned enjoying rubbing the grooves with their fingertips which was not the intended use of the grooves but an added benefit.

Using Insights about Children's Fidgeting Preferences

During the design process, I chose to use insights gleaned from my prior research with children regarding their fidgeting interaction preferences (see Chapter 2 for full study details) to shape my design. All of the adults in the study gravitated to one or more of the children's preferred fidgeting interactions which shows promise that children's fidget evidence can be useful for designing adult fidget objects.

Good Enough?

At the onset, my goal was to create a smart fidget device that the majority of people would want to interact with. My goal was not to create a fidget that only tracked interactions that everyone would love but rather to design and build a smart fidget that could track several interactions so that the majority of people would gravitate towards interacting with at least one of them. I accomplished this goal. While the Fidgegtato may not be everyone's perfect fidget object, as can be seen from the design alterations evident in the clay models, all of the participants found engaging in one or more of the tracked interactions satisfying which is better than the majority I was hoping to attract. Therefore, I feel comfortable continuing forward with using this fidget tracking device for fidgeting research.

3.5 Conclusion

In conclusion, we designed and built a fidget tracking device, "*Fidgetato*", that captures fidgeting traces to aid in fidgeting research. The *Fidgetato* was designed using information on fidget object preferences obtained from previous studies on adult fidgeting objects [27] and my prior research into children's fidgeting interaction preferences [10]. By incorporating previously identified interaction preferences, I hope to be able to not only study fidgeting with respect to focus, retention, and self-regulation but also determine if relationships between fidgeting interactions and certain activities and mental or emotional states identified in my earlier work with children can be supported with adults. Additionally, relying on results from a children study to design a fidget object intended for adults raised the question of whether or not adults will like interactions identified as preferred by children.

After building the *Fidgetato*, I conducted a user study to get feedback on the device itself and whether or not potential users liked and interacted with it as intended. My study found that while most of the participants found one or more dimensions of the *Fidgetato* bigger than what they would deem optimal for themselves, all of the participants were able to interact with the object in one or more ways that they found satisfying. Given the wide variety of fidgeting interaction preferences (as shown in Karlesky's prior research [27] and mine), creating one object that all adults would enjoy and that would contain all of their favorite interactions is not possible. My goal was to create an object that the majority of adults would enjoy by providing one or more interactions that they find satisfying so my user study confirmed that I had met my goal.

I saw the preliminary study as a necessary step to validate the design of the *Fidgetato* before using it for studies into fidgeting behavior, costs, and benefits because I wanted to ensure that we are providing appropriate affordances with the *Fidgetato* for it to be viable for various kinds of fidgeting studies. That is why I used an evidence based approach. I now feel comfortable moving forward with the *Fidgetato* to the next stage of my research.

In addition to verifying the viability of the *Fidgetato*, the results of my study led me to conclude that while interactions preferred by children might not be the top interaction preferred by adults, they are still interactions that adults gravitate towards and as such, children's fidget interaction preferences can inform the design of adult fidget objects. I believe that this result coupled with the feedback on fidget interaction, shape, and material preferences that I received while testing the *Fidgetato* might be of interest to researchers designing fidgets and other tangibles.

I plan to use this fidget object in future research that aims to help answer the questions of whether and how fidgets may help with cognitive performance, or whether and when using them can become detrimental.

Chapter 4

Analyzing a Pre-existing Online Dataset For Insights into Adults' Fidget Object Preferences

4.1 Introduction

While fidgeting is a commonly observed behavior and fidgeting items are increasingly popular, the effects of fidgeting are still being studied. Popular perception overwhelmingly associates fidgeting with inattention [7, 14] with many perceiving it as a disturbing behavior [13]. However, there exists some evidence of the possible benefits of fidgeting [4, 33, 41] including the potential to regulate focus [8, 12, 31, 38]. Smart fidget tracking objects could help us study these effects. However, they must be designed so that people want to use them.

Identifying which properties attract people to interact with a fidget object can not only inform the creation of good smart fidgets for fidgeting research, but also inform the design of other tangibles. My study focuses on gaining insights into adult fidget object preferences. In the tradition of using social media as a research tool [3, 32], I analyzed an existing dataset on Tumblr, Michael Karlesky's Fidget Widget Tumblr (https://fidgetwidgets.tumblr.com/). A Tumblr is a "cross between a social networking site (like Facebook and Twitter) and a blog" [43] that allows for solicitation of users' posts concerning a defined topic. Karlesky's Fidget Widget Tumblr has already collected a substantial catalogue of preferred adult fidget objects. Though this dataset was previously analyzed [27], it has accumulated almost double the submissions since that study was conducted, and the earlier analysis was not a thorough catalogue of fidget qualities, nor was it analyzed through the lens of my more recent work on fidget preferences (see Chapter 2) [10]. Furthermore, in light of my work on children's preferences, an analysis of how adult preferences compare to children's can now be conducted.

I was further interested in finding out whether analyzing this pre-existing Tumblr dataset would yield insights of similar depth to those obtained from a more time and labor intensive multi-stage study like the one conducted with children (See Chapter 2) and what the inherent benefits and drawbacks are of conducting analysis of this type.

4.2 Related Work

The market is filled with fidget objects which claim to aid focus and retention or self regulation. with a growing number of studies concerning whether or not fidgeting with those specific objects is beneficial. Some studies find positive outcomes for fidgeting [8, 41], while others find negative outcomes [22, 40].

Though limited research exists regarding fidget object creation, the debate over whether fidgeting is beneficial or detrimental can be clearly seen in the stark differences between Karlesky's and Yuan's work. Karlesky [24, 25, 26, 27] encouraged fidgeting by creating fidget objects referred to as Fidget Widgets which were playful in nature and created to "support a user's productivity and creativity". Conversely, Yuan discouraged fidgeting by creating a jacket designed to signal when the wearer is fidgeting, so that the behavior can be stopped [29].

Two bodies of work have explored fidget object properties: Karlesky's and mine. Karlesky's Fidget Widget work [24, 25, 26, 27] started by observing fidgeting in the wild and then using those observations to create and test a fidget object that people could use while working. Karlesky went on to create and analyze a Tumblr on adult fidget objects. His work describes the fidget objects submitted to the Tumblr as being diverse, having a narrative, affording a multitude of interactions, comprising various materials and form factors. His observations continue by discussing what people get from fidgeting (for instance tactile interaction, self-regulation, or enjoyment). My work differs from the above mentioned work in that it not only observes that there is a variety of form factors, materials, and reasons for use but also attempts to group the items submitted into categories that illustrate these various dimensions.

In my prior work involved a multi-stage study with 54 participants of which 28 were children, 24 were their parents, and 2 were their teachers. This study identified children's fidget object material qualities, interactions, and form factors preferences, in addition to finding relationships between fidgeting interactions and activities or emotional states (see Chapter 2). This work differs from my previous work in that it gains insights into adult fidget object preferences rather than children's and uses the findings of that study to compare with this one to see whether or not the identified children's preferences are applicable for an adult population.

4.3 Methodology

For his work on fidgeting objects, Karlesky set up and analyzed a Tumblr (https://fidgetwidgets.tumblr.com/) to solicit and collect "simple free-form photo, video, and text submissions as to items, fiddling manipulations, and sensations experienced" while fidgeting [27]. The Fidget Widget's Tumblr has the following submission prompt:

> *Ever notice how people play with some kind of a thing — pen, paperclip, stress ball, magnets, marker, etc. — while lost in thought as they work? Maybe you do it too. There's a powerful link between the hand and the brain. Research shows that our feelings, thoughts, and body are very much interconnected. Our Fidget Widgets project is exploring this behavior and the opportunity for small, tangible, digital interactions to tap into what happens while people fiddle with objects as they work. Think of a Fidget Widget as an indirect productivity tool aiming to subtly enhance your creativity, or give*

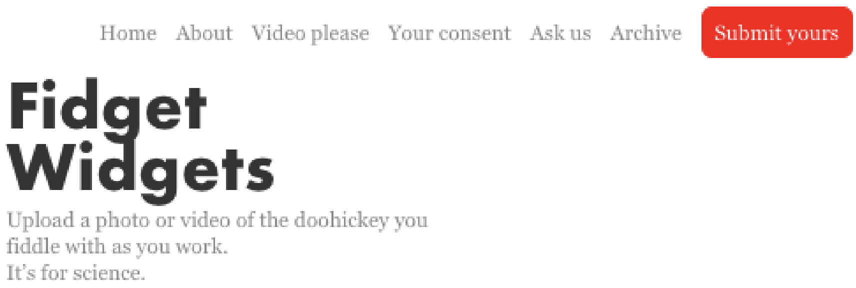


Figure 4.1: Karlesky's Fidget Widget Tumblr Header.

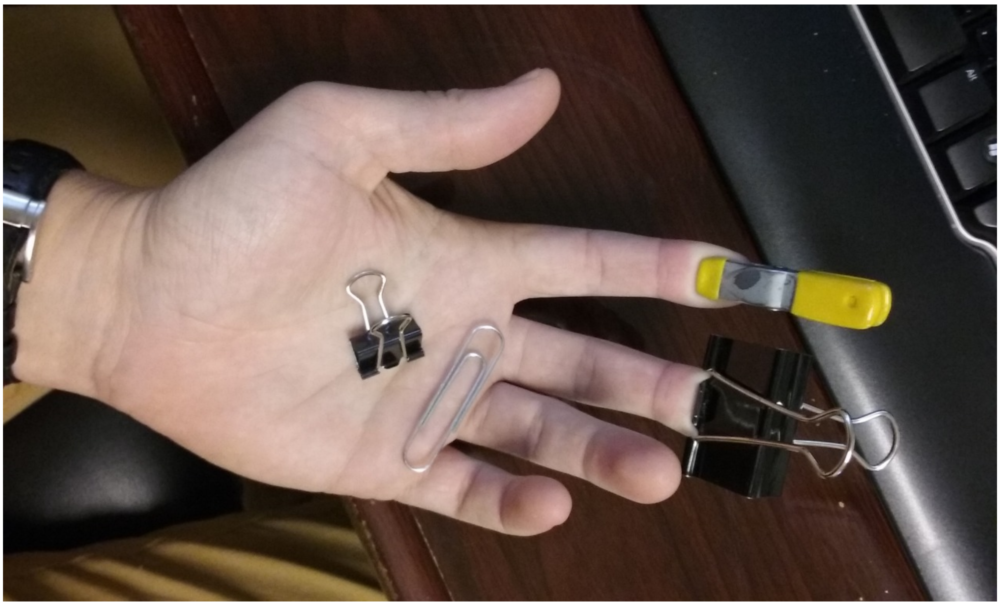
you focus, or decrease stress just when you need it. What we've learned so far is that users strongly desire a very pliable, stimulating, and satisfying tactile experience in their hands. And that brings us to this tumblr. We're conducting design research here, collecting examples of items and materials and ways in which people fiddle with objects while at work.

The Tumblr was promoted through personal connections, word of mouth, social media, newsletters, and several newspaper articles. All of the submissions to date are viewable by the public in the archive (https://fidgetwidgets.tumblr.com/archive). At the time of this analysis, the Tumblr archive contained 169 submissions. Its header is shown in Figure 4.1.

I started by cataloging the submissions, noting all of the information provided in a submission: pictures, videos, and accompanying descriptions. When provided, the location, activity, emotional state, and/or benefits associated with the fidget item were noted, along with the physical properties and inherent interactions. I further noted and made a separate entry for each fidget object that a submitter mentioned, independent of whether or not a picture of that object was submitted. This resulted in a preliminary count of 239 fidget objects from 169 submissions. Additionally, I noted interactions that were possible with the given object even if not specified by the submission. This is because fidgeting is often an activity that people engage in without conscious thought, so it is possible that there are interactions that the submitter engages in that are not specified in the write up, even if the submitter attempts to be thorough in his/her description. Another reason for this is that many submissions did not provide any information regarding the fidget's use. As an example of this, I noticed three submissions (submissions 79, 86, and 92 - see Figures 4.2 thru 4.4 for submission pictures and accompanying text) with pictures of similar fidgeting objects (metal binder clips) that had vastly different written submissions. Since submission 92 did not contain any information on usage, I looked to submissions 79 and 86 to gain information on the possible interactions provided by the fidget object.

After all of the data was catalogued, I started closely examining the data and noticed that four of the submissions were done in support of earlier submissions. For instance, submission 76 from July 24, 2015 is a picture containing both a stress ball and a slinky, and submission 77 from the same date is a video of the same submitter interacting with both fidget objects. Due to the subsequent submission merely providing additional information in these four cases, I adjusted my unique submission count to 165, with a total of 235 objects described.

After further deliberation, I chose to eliminate three additional items from my



I actually found this tumblr page by Googling "Why do I fidget with metal things?". I am constantly fidgeting with those little metal breifcase-looking clips as well as this little metal clip with yellow plastic coating on it. It feels really good and seems to relieve my stress to clip them to my fingertips. Paperclips are a good too. Plastic things like pens and markers don't give me the same feeling, it's got to be metal and I prefer the clips because I can squeeze them open repeatedly.

Figure 4.2: Submission 79.

Sometimes I fiddle with a mechanical pencil or pen, but lately this binder clip I found in my office desk has been my object of choice. Not only can I twirl it between my fingers like one would a pen or pencil, I can "fold" it back and forth while twirling, almost like rigid silly putty. Rather than running along one axis like a pencil, the binder clip can have multiple, moving axes. I'll also clip it onto the folds of skin that form on the uppermost part of your palm when you bend your fingers forward or onto one of my fingers. Opening the lips of the binder clip incorporates aspects of a stress ball, but, like the multiple axes compared to a pencil, the binder clip gives me more options in how I choose to squeeze it, depending on I how hold it in my hand and between which fingers I squeeze. It really is interesting how a boring binder clip can incorporate several aspects of other common "fidget-able" items.

Figure 4.3: Submission 86.

Figure 4.4: Submission 92.

analysis: item 10 (one of the three fidget objects mentioned by submission 6), item 223 (one of five fidget objects mentioned by submission 155), and submission 127 in its entirety. I chose to eliminate items 10 and 223 because the submissions mentioned them as something that had been ordered, but had yet to be received, much less used, so information on whether or not they provided the user with the interactions/stimulation that the user was seeking was purely speculative. For example item 223 contained the following in its writeup:

> *I think the next thing I'm going to try is something called an Italian Charm Links Bracelet.*

Item 127 was discounted because it contained the description of an object that the submitter had taken part in manufacturing for sale to children. Since to my knowledge the object was neither intended for nor used by the submitter, I chose to view it as product marketing and eliminated it from my analysis. These two eliminations left me with a total of 164 submissions with a total of 232 fidget objects.

After I had culled the data to reflect real use information, the data set was analyzed and the submissions were grouped together based on their physical characteristics or inherent interactions, in addition to when used (e.g. at work) and why (e.g. when sad or stressed). Due to the nature of the groupings, most objects can be placed in more than one grouping. For instance, a magnetic object that is used when concentrating would be in both Magnetic Things and Focus Concentration.

4.4 Results

4.4.1 Most Frequently Mentioned Fidget Objects

First I noted type matches, tabulating objects that were roughly the same thing, regardless of use, texture, size, color, or material make up and found that the four most frequently mentioned fidget objects were pens/pencils, body parts, paperclips, and stress balls. Examples of these items can be seen in Figure 4.5.

After much deliberation, I found that the overall collection of seemingly dissimilar objects were actually very similar along several different dimensions. For instance, the intended benefit of using two objects may be the same even though their form and the interactions that they provide might be very different. Viewing the collection of objects in this way, I was able to form 12 groupings of objects based on their material

Figure 4.5: Most Frequently Mentioned Fidget Objects

qualities, primary interactions, intended purpose of use, and reasons for fidgeting. The objects in each group can vary widely as long as they are similar in that dimension. These groups are not mutually exclusive so many of the objects in the study fit neatly into several groups. I present each of the 12 groups clustered into one of four categories: Material Properties and Form Factors, Interactions Provided, Secondary Purpose, and Contexts of Use.

4.4.2 Material Properties and Form Factors

The groupings in the Material Properties and Form Factors grouping are defined by their physical material makeup or shape.

4.4.2.1 Ball-like Fidget Objects

With the exception of the small glass vials, the objects in the Ball-Like Fidget Objects group were round or roundish. All of the objects (see Figure 4.6) are used for one-handed manipulation in a rolling or juggling type of movement in the palm of your

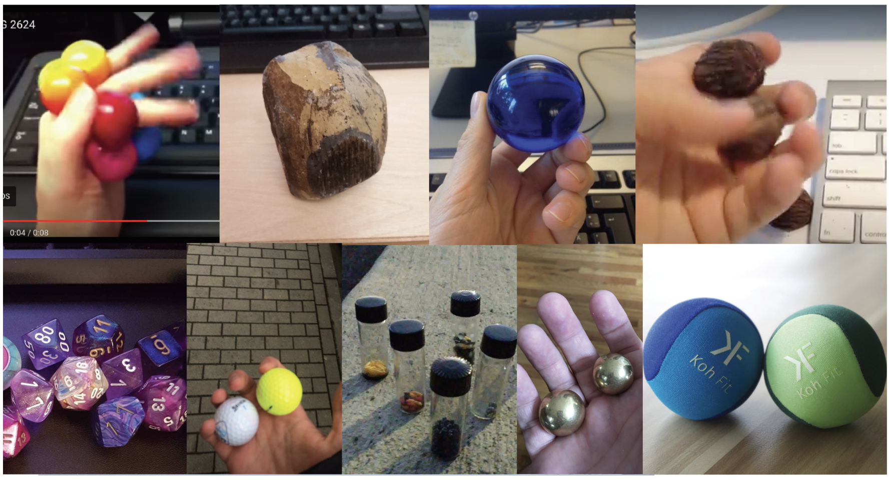


Figure 4.6: Ball-Like Fidget Objects

hand. Written submissions of these objects included videos or written descriptions of how they were interacted with and sometimes also included how they served the person. Examples include *"it goes round and round and keeps the ideas coming"* and *"I roll them around, either in my pocket or my hand...I take them out when I'm listening intently"*.

4.4.2.2 Magnetic Things Fidget Objects

All of the items in the Magnetic Things grouping (see Figure 4.7) provided preferred interactions due to their magnetic qualities. Descriptions of these objects included *"it has a magnet inside, which makes it extremely satisfying to play with. I noticed that I use it in a variety of moods: sometimes it helps me focus...other times..reduces my social anxiety"* and *"As I work, I fidget with my magnetic Microsoft pen. I like pulling it off the side of my laptop and having it snap back on. I do this a lot as I am reading something on my laptop to help me focus"*.

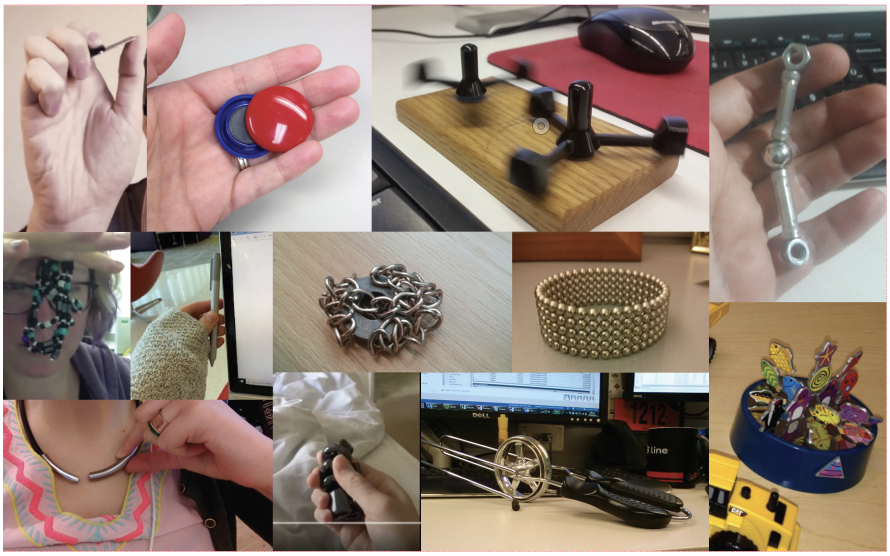


Figure 4.7: Magnetic Things Fidget Objects

4.4.3 Interactions Provided Category

While the objects in the Interactions Provided Category vary greatly, they all afford the same type of interaction despite their different shapes and material qualities.

4.4.3.1 Twisty Things

As can be seen from Figure 4.8, the items in the Twisty Things grouping are very different, yet from the EOS chapstick ("I repeatedly take the lid off and put it back on) to the old fashioned bottle opener ("Twisting the handle turns the gear and the jaws open and close back and forth"), they all provided a twisting interaction that appealed to the the user. There were several Rubick's Cubes among the submissions. Their descriptions included: *"to keep from getting too distracted at work when I'm waiting on my computer to finish loading or processing something. I don't even always solve them.*

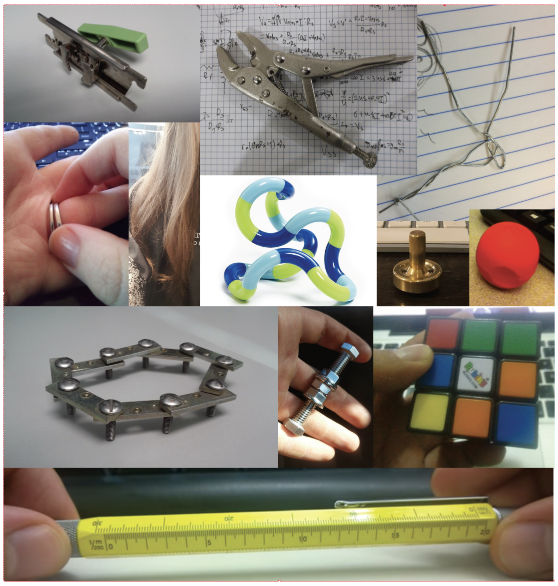


Figure 4.8: Twisty Things Fidget Objects

A lot of times I just like to flick the faces of the cube around ... I just like the smooth rotation of the pieces." and *"when I'm playing with this, I'm a lot calmer and can focus much more"*.

4.4.3.2 Sensation Seekers

While all fidgeting provides some degree of feedback just from the mere act of interacting with an object, from how it feels in your hand to how you move your body to interact with it, there seems to be a spectrum of sensation seeking that motivates some fidgeters to gravitate towards items that will provide a higher degree of tactile feedback. I describe this group seen in Figure 4.9 as Sensation Seekers, since they provide a higher than average amount of feedback, primarily because many of them are parts of the fidgeter's own body. As an example, someone who fidgets by repeatedly

Figure 4.9: Sensation Seekers Fidget Objects

tapping their fingertips or by pulling their hair gets both the experience of pulling and tapping, and also the experience of being pulled and tapped. “Objects” include but aren’t limited to nails, hair, skin, and fingertips. Interactions listed with these included biting, rubbing, pulling or twisting hair, tapping, scratching, and pinching. In addition to these, metal binder clips were added to the grouping as two submissions specifically mentioned attaching them to their body: *“I’ll also clip it onto the folds of skin that form on the uppermost part of your palm when you bend your fingers forward or onto one of my fingers.”* and *“It feels really good and seems to relieve my stress to clip them to my fingertips.”*

Figure 4.10: Convenience Items Fidget Objects

4.4.4 Secondary Purpose Category

The Secondary Purpose category contains two groupings with objects that were originally intended for other purposes and were appropriated to satisfy the submitter's need to fidget.

4.4.4.1 Convenience Items

Many multi-purpose objects were among the submissions. After analyzing them, I realized that they fell into two broad categories. The first and by far the largest, is the category that I termed Convenience Items (see Figure 4.10 for a sample of the range of these items). These are items that you would typically have on your person or around your work space. Fidgeting with them does not require carrying anything extra with you as the items are easily accessible. Examples include jewelry, phones, earphones, USB flash drives, body parts, paperclips, rulers, sticky notes, pens, and pencils.

Figure 4.11: Quirky Repurposed Fidget Objects

4.4.4.2 Quirky Repurposed Objects

The next group of multi-purpose objects I termed Quirky Repurposed Objects (see Figure 4.11). These are items that were purposefully brought into the workspace so that they could be used as fidget objects. These are items that are either used for work but have been altered in some way to provide the fidgeting interaction that the user needs thereby making them unique and different from other items of their type typically found in the workspace, or else they are meant for purposes completely unrelated to their job and workspace. An example of an item that is usually found in the workspace but has been altered for fidgeting is the pencil with an added screw and washer topper as shown in the bottom right of Figure 4.11.

Figure 4.12: Thinking Fidget Objects

4.4.5 Contexts of Use Category

The Contexts of Use Category is comprised of groupings formed based on how fidgeting served the people who submitted. In essence, these groupings answer the question of why they fidget, how they think that it serves them. Entries that answered this question contained descriptions that included words and phrases that alluded to the activity they were engaged in or the mental state they were experiencing while they were fidgeting. They included words like: calming, focus, boredom and activities related to working/thinking.

4.4.5.1 Thinking Objects

All of the items in this group (example seen in Figure 4.12) had descriptions that referenced directly or indirectly the idea of thinking. Examples of some of the phrases associated with these items are as follows: *"when I'm stuck on a software*

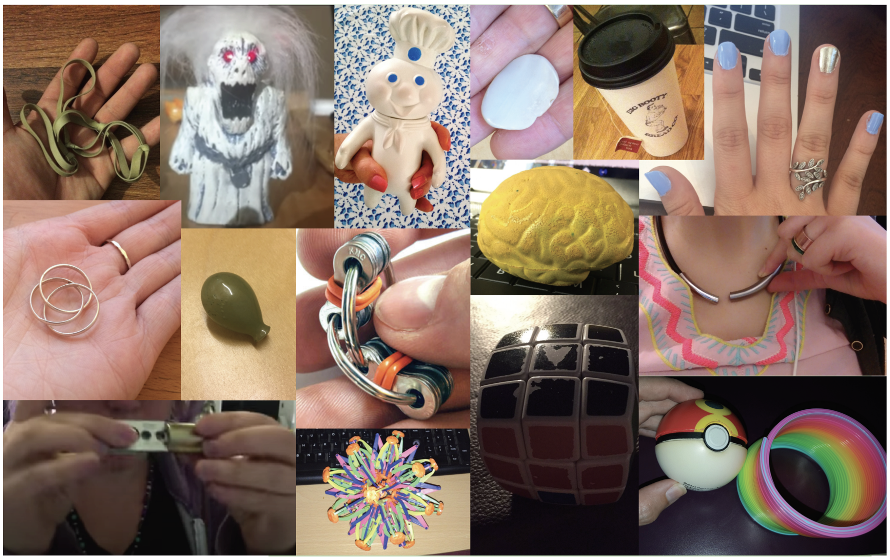


Figure 4.13: Calming/Soothing/Relaxing Fidget Objects

programming problem or while figuring out how to express an idea in written form", *"while I am thinking"*, *"seems to jump-start the creative process"*, *"when I am puzzling through the best way to write a formula/code or looking for trends in data."*, *"to keep my brain going"*, *"something about the gears and motion help me code"*, and *"help(s) me think"*.

4.4.5.2 Calming/Soothing/Relaxing

The items in this category (example seen in Figure 4.13) were all associated with descriptions which mentioned that they aided the submitter by relaxing, calming, or soothing or in some other way provided stress or anxiety relief. In the written descriptions included with these objects, when the submitter describes why they are fidgeting with it, they use words like *"stressed"* and *"anxious"* often in conjunction

Figure 4.14: Focus/Concentration Fidget Objects

with words like: *"reliever"*, *"reduced"*, *"alleviate"*, *"relief"*, and *"copes"*. When describing how it serves them, they use phrases containing the words *"calming"/"calmer"*, *"relaxed"/"relaxing"*, *"comforting"*, *"meditative"* and *"soothing"*. As an example, submission 153 stated *"is comforting. I have a lot of anxiety that would be unmanageable without this little guy. I never go anywhere without it."*

4.4.5.3 Focus/Concentration

The grouping of Focus/Concentration items (see Figure 4.14) contained descriptions that mentioned that the object reduced how distracted they get from other things or helped them to focus, concentrate, or pay attention. These submissions contained wording such as: *"can focus so much more"*, *"whenever I need to listen attentively"*, *"helps me pay attention"*, *"keeps me engaged"*, *"whenever I'm having a hard time focusing"*, *"helpful to concentrate"*, *"increases concentration"*, and *"I listen better"*.

Figure 4.15: Boredom/Waiting Fidget Objects

4.4.5.4 Boredom/Waiting

The objects in the Boredom/Waiting grouping (see Figure 4.15) were all used when the fidgeter was either bored or waiting for something. While many of these objects were also used when the submitter was anxious or stressed, all of the objects in this group were described as used when the person was bored or waiting for something. Examples of wording used to describe the objects include: *"when I have nothing to do"*, *"can help get through the boring"*, and *"while I wait for code to run"*.

4.4.5.5 Re-directed Fidgeting Behaviors

Several items had descriptions that specifically mentioned that the fidget object helped them re-channel their physical movements away from destructive habits (see Figure 4.16). Examples of this are:

Figure 4.16: Re-directed Fidgeting Behavior Fidget Objects

Submission 6 (the prayer beads): *"I have a lifelong history of fidgeting that's connected to ridiculous adult nail biting. Super embarrassing. If I'm fidgeting, I'm not biting my nails, but if I lack for a fidget thing I'll bite my nails."*

Submission 164 (Fidget Cube): *"This stopped me from picking at my hair all day whenever I do coding and stuff."*

Submission 115 (Magnetic Hermatite stones): *"I used to pick at my hair when I was working/thinking/anxious which was no good. I struggled to find an alternative…These magnetic hematite "sticky stones" are perfect…"*

Submission 117 (Fidget Cube): *"It's been very good at keeping me from messing with a pen...previously, I've literally...thrown a pen a good few feet away because I wasn't paying attention to it and lost control."*

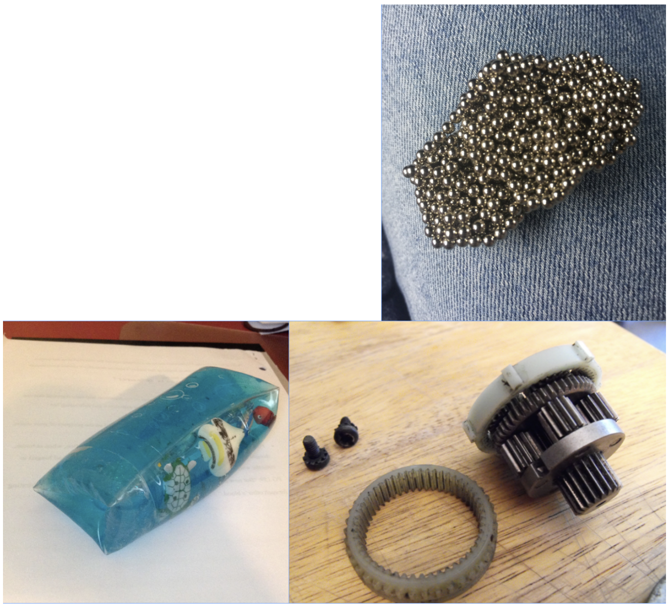


Figure 4.17: Entertaining Fidget Objects

4.4.5.6 Entertaining Objects

All of the items in the Entertaining Objects group (see Figure 4.17) had descriptions with wording that depicted how fidgeting with them held their attention. Three examples of this are as follows:

Submission 54: *"It is filled with some type of liquid, cool and squishy to the touch and easily flips inside out through a hole in the middle. It keeps me mindlessly entertained for hours."*

Submission 146: *"I like machinery and mechanical elements to begin with, and the relationship of motion between the parts is absorbing."*

Submission 162: *"It's just little tiny magnets, but it keeps me totally entertained."*

4.5 Discussion

I set out to gain insights into adult fidget preferences from a pre-existing Tumblr dataset. The large quantity of Tumblr submissions gave me a sense of the wide variety of preferred adult fidget objects and enabled me to see shared traits from among seemly very different fidget objects. I was then able to create groupings of objects based on these shared properties. The groupings created fell into one of four categories: Material Properties and Form Factors, Interactions Provided, Secondary Purpose, and Context of Use.

Additionally, I planned to compare the insights obtained from this Tumblr dataset with that earlier study to see if children's preferences extend into adulthood, and if guidelines found for that population can be used when considering the choice or creation of adult fidgets. However, each study's data had distinctive properties that led to different sets of information which hampered a direct comparison of all aspects identified in the prior study. The Tumblr dataset had a far larger number of people and objects associated with it, which allowed for a really close dive into the material properties of adult fidgets in a way that that other study could not provide, but it has less rich information about the patterns of usage. This is due to submissions only containing the information that the poster deemed relevant. As opposed to this, in the in-person children's study, I was able to get the same questions answered from each participant. I was able to identify some similarities and some differences nonetheless.

For my dataset, 109 people out of 164 (66.5%) provided information about when or why they fidget. From that subset of the submissions, it is clear that adults fidget for much the same reasons that children fidget. Reasons given ranged from emotion regulation (anxiety, stress) to aiding concentration and focus. As with the children's study, working/studying was the most frequently mentioned activity when fidgeting, with roughly half (54 of 109) people citing work or study related reasons for their fidgeting.

The ways in which fidgeting helped the participants were also similar to children, with benefits being reduced anxiety/stress, and increased calm/relaxation and focus/concentration. However, a major difference is that while children mentioned anger as a reason for fidgeting, enough so that a relationship between the squeezing interaction and that emotion was identifiable, adults never mentioned anger as a reason why they fidget. It is possible that this is because unlike adults, children have yet to learn how to deal with anger in a way that does not risk breaking things. It is also possible that since children have less autonomy over their lives and situations than adults have, that they have less choice in how to self regulate. What this might mean for designers of fidgets and other tangibles, is that while the children's study found that fidget objects needed to be really durable in order to withstand rough fidgeting, it is not as much of a consideration for adults. Another difference is that children often cited excess energy/restlessness as a reason for fidgeting, while out of this much larger group of participants only one adult did. This also could be attributed to adults having more agency over when they come and go lessening their need to expel excess energy from having to remain in one place.

In terms of item choice, both adults and children often chose to fidget with items that are convenient or multipurpose, with both children and adults citing squeeze balls and pen/pencils as two of the most popular items mentioned. The difference between the two groups seems to be motivation for choosing convenience/multipurpose items. With children, due to adult supervision, the need to hide fidgeting by interacting with objects that blend into the workspace was given as a primary motivator for choosing those items. The children "made due" with interacting with items that they thought they could get away with. Conversely, only one adult mentioned trying to hide fidgeting by using convenience items. Due to the large number of items submitted and the wide variety of items used, it is clear that stealth while fidgeting is not a primary motivator when choosing fidget items by adults.

It was interesting to see that choosing to fidget with parts of your own body did not go away as children become adults. While both children and adults mentioned fidgeting with parts of their bodies, the children in that study did not mention any of the more extreme sensation fidgeting that I saw from the adults. They mentioned twisting their hair or putting it in their mouths but not pulling it out. Nor did they mention doing anything that would give the amount of feedback that attaching a binder clip to the end of your finger does. There is already a wealth of clinical research about when that gets out of hand, such as hair pulling and cutting, but it is interesting to note that there were a couple of examples of people transferring those kinds of habits onto objects. Their need for objects to occupy themselves so that they will not engage in detrimental habits underscores the need for a physical release of some type. Perhaps when not channeled into other forms of release, the need for stimulation grows as people age. It would be interesting to see if fidgets aimed at targeting this population could help them curtail their more destructive or painful habits.

In general, both children and adults fidget. Both groups also look to find objects that provide the interactions that resonate with them. The effort to which people go to be able to fidget in a way that appeals to them or serves them in some way emphasizes their need for that release or channeling of physical energy. Further study is necessary to find out more precisely what adult preferred interactions and reasons for fidgeting are, since many of the objects in the study did not come with descriptions providing that information.

In analyzing the data, I noticed that the main limitations of analyzing a data set of this type is that each person submitting to the Tumblr can choose what information they want to include with their submission and that I am unable to circle back to them for followup information to gain further clarity or insights on their submission. However, due to the volume of submissions, I was able to detect common properties among divergent objects that I would not have been able to discern from a smaller data set like the one obtained from my prior in-person children's study. Therefore, I found that analyzing the Tumblr dataset yielded information that while different from my previous study, was of similar depth to be beneficial for researchers.

4.6 Conclusion

In conclusion, a pre-existing online data set on Tumblr was analysed for insights into adult fidget object preferences. Due to the sheer magnitude of submissions to the Tumblr, I got a sense of the rich variety of preferred fidget objects in the wild. From this wealth of fidget object data, I was able to discern commonalities among seemly diverse objects and thereby create groupings of fidget objects with each fidget object having the potential, based on it's properties and accompanying information, to to be in more than one grouping. These groupings are classified into four categories: Material Properties and Form Factors, Interactions Provided, Secondary Purpose, and Contexts of Use.

While I was able to gain interesting insights into adult fidget preferences from the Tumblr dataset drawing a comparison between children's preferences and adults' preferences was complicated by the differences in the two datasets. However, I was able to compare many of the aspects of fidgeting found in that prior study. My findings included noting that while adults and children fidget for much the same reasons, unlike for children, designers need not consider durability and stealth when creating adult fidget objects.

I did find a lot of interesting trends in these patterns of interactions for adults which could be useful for future smart fidget development. As this dataset illustrates, people chose to interact with a very diverse set of objects with very different material properties, however these objects do have some commonalities that may become interesting dimensions for future study. Our research team has ongoing projects developing smart and interactive fidget objects, and we plan to use this analysis to guide our work. I hope that this information is also useful to others in the community interested in the phenomenon of fidgeting and designing smart objects to support fidgeting. In addition, I hope that these insights are useful toward building better tangibles that invite the user to engage with them like fidget objects do.

Chapter 5

Not All Fidgets Are Created Equal: Exploring Fidgeting's Impact On Focus And Retention Using An Electronic Fidget

5.1 Introduction

Fidgeting is a ubiquitous behavior. It is so commonplace that an entire industry has evolved to create and sell various fidget objects, from fidget cubes to the more recent push bubble fidget toys. In addition to purporting to satisfy people's need to fidget, many come with claims of enhanced focus and retention or self regulation. For instance, fidget cubes are marketed as "An unusually addicting, high-quality desk toy designed to help you focus."[2] and push bubble fidget toys are marketed "for people to relieve stress and anxiety" [1]. Despite what the marketing campaigns lead the public to believe, experts are still split over the validity of those claims. Some studies have found benefits to fidgeting [8, 38, 41] while others have found detriments[17, 22, 40]. These conflicting studies leave even the informed consumer unsure whether to curtail or continue engaging in and possibly increasing the behavior.

One recent study by Soares found memory impairments related to fidgeting with fidget spinners [40]. Upon reviewing that study, I wondered whether the memory impairment observed would hold true across all fidgets or if it was due at least in part to using a fidget spinner rather than some other fidget object possibly more suited to the tasks in the study. To investigate this question, my study replicates the second part of that study using an electronic fidget named the Fidgetato (See Figure 5.1 for images, creation and preliminary testing can be found in Chapter 3) capable of tracking fidgeting interactions. The design of the Fidgetato includes three interactions (pressing, clicking, and squeezing) found to be very popular among children in my prior research(see Chapter 2 for full details). In addition to being very popular, two of these interactions, pressing and clicking, were also found in my prior study to have a bi-directional relationship with cognitively demanding activities. Since people gravitated toward these interactions during cognitively demanding activities, I thought that they might not cause the same memory impairment found in the Fidget Spinner study.

In this paper, I present the details of my study and discuss my findings on the impact of different types of fidgeting on focus and retention. Through these results, I show that not all fidgets are created equal and that we as designers must be mindful of that so as not to create fidget objects that impair memory.

5.2 Related Work

Despite the ubiquitousness of fidgeting in society and the various claims by fidget object makers of increased focus and retention or self regulation, experts have yet to come to a consensus on the validity of these claims. [36] Some studies have found that fidgeting can be beneficial [35, 41] with several studies positing fidgetings positive affect on focus and retention [4, 8, 31, 38].

Conversely, recent studies found memory impairments associated with fidgeting [17, 40]. In one of these aforementioned studies, Soares et al. explored the impact of fidgeting on focus and retention. The researchers conducted a within-subject study comparing two conditions: with a Fidget Spinner and without a Fidget Spinner. The participants were tasked with watching a video, doing a different task for 5 minutes (Corsi blocks), and then taking a test on the material covered in the video. They found fidget spinners to negatively affect both the participants' performance on the test and their self reported attention during the video.

While the researchers confined their analysis to the effects of Fidget Spinners, their findings spurred my curiosity about whether or not the memory impairment that they identified would extend to fidget objects in general. Hence, I decided to conduct a similar study using an electronic fidget object (the *Fidgetato*) that according to my

	Video One	Condition	Video Two	Condition
1	Kamehameha	Without Fidgetato	Ned Kelly	With Fidgetato
2	Kamehameha	With Fidgetato	Ned Kelly	Without Fidgetato
3	Ned Kelly	Without Fidgetato	Kamehameha	With Fidgetato
4	Ned Kelly	With Fidgetato	Kamehameha	Without Fidgetato

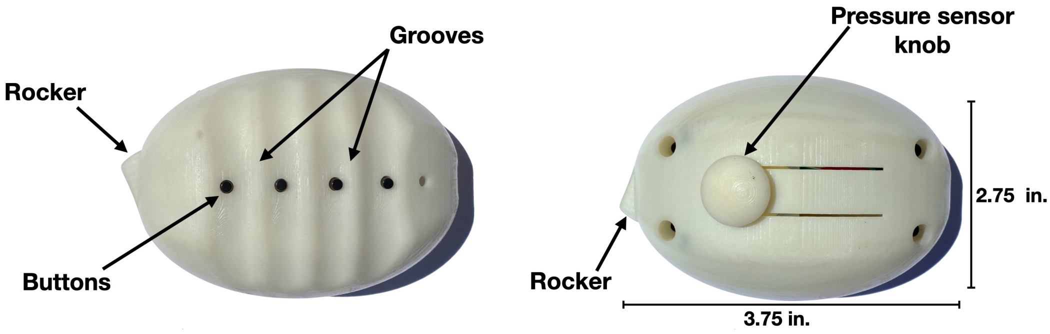
Table 5.1: Four Study Combinations

previous research (see Chapter 2) was possibly better suited to cognitively demanding activities due to two of its inherent affordances: pressing and clicking.

5.3 Methodology

My central research question was whether or not the memory impairment observed in the recent fidget spinner studies occurs with all fidgets. In order to answer this question, I decided to conduct a study on the effects of fidgeting on focus and retention using a fidget object that was possibly better suited to cognitively demanding activities given its inherent affordances. If my study failed to find the memory impairment observed in the Fidget Spinner studies, then I would know that all fidgets do not cause memory impairments but rather only some of them do.

The study was designed based on Soares' recent fidget spinner study [40] and used many of the same materials. Hence, I used the same animated educational videos which were chosen by the prior study due to their length and lesser known subject matter: *Ned Kelly - Becoming a Bushranger - Extra History* and *Kamehameha the Great*



(a) Front View (b) Back View

Figure 5.1: Fidgetato

- *The Lonely One - Extra History*. There were two (within-subjects) study conditions: with fidget and without fidget. This created four possible study combinations (see Table 5.1. Participants were randomly assigned a study condition with a quarter of the participants assigned to each combination.

The major difference between my study and Soares' is that I am using an electronic fidget object, the *Fidgetato*, rather than a fidget spinner. The *Fidgetato* (see Chapter 3) was designed specifically for use in fidgeting studies. Unlike the fidget spinner which affords only hold and spin interactions without any interaction tracking capability, the *Fidgetato* affords those interactions in addition to affording and tracking three interactions found to be popular in my previous research: pressing, clicking, and squeezing.[10](See Chapter 2 for study details). Two of these interactions, pressing and clicking, were identified by the same research to be correlated with cognition, which makes the *Fidgetato* well suited to a study of this nature. In addition, the *Fidgetato's* tracking capability added another layer of information with which to conduct analyses.

The study sequence was the same for all participants (52 adults ranging in age from 19 to 73) for each video assigned. Hence, each participant completed the following sequence twice: Video, Questionnaires, Distracting Activity, and Fill-in-the-Blank Test. The only difference between the two iterations was that directly before starting the sequence with the *Fidgetato*, I explained the function of the *Fidgetato* to each participant and demonstrated several ways in which it could be held and interacted with. The participants were told that they must hold the *Fidgetato* for the entirety of the video after which time they could either hold it or not for each of the remaining activities in the sequence. Participants were further informed that while they must hold the *Fidgetato* for the video, they need not interact with it unless they chose to do so. The *Fidgetato* was turned on immediately before handing it to the participant at the start of the video.

5.3.1 Video

Each participant was tested separately in a quiet environment and asked to turn their phones off, lessening any distractions from the assigned tasks. Videos were played on a 13-inch laptop monitor. Participants were directed to watch the assigned video carefully as they would a class lecture.

5.3.2 Questionnaires

Participants were then asked to fill out an Attentional-lapses questionnaire to determine how well they were able to focus on the video content under each condition.

I noticed myself mind-wandering about things directly RELATED to the video 1. Never 2. Rarely 3. Sometimes 4. Often 5. Very often
I had difficulty staying on task while watching the video 1. Strongly disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly agree

Figure 5.2: Attentional-lapses Sample Questions.

See Figure 5.2 for sample questions or the appendix for the questionnaire in full.

Following the Attentional-lapses questionnaire, the participants were asked to estimate how many questions they thought they could get right on a 15 question fill-in-the-blank test about the video they just watched. This Judgement of Learning question was asked to see if they felt confident about their grasp of the subject matter and if they could realistically estimate how much of the information they had retained from the video.

5.3.3 Distracting Activity

Next, each participant was given a distracting activity to perform for five minutes to take their mind off of what they had just learned. I had participants play Sudoku online. Each participant was free to chose the level they wanted to play.

5.3.4 Fill-in-the-Blank Test

After playing Sudoku for five minutes, the participants were given a fill-in-the-blank test (See Appendix for tests) on the material in the video. There was no time limit given for the test. The tests were checked to see if the answers written exactly matched the answers provided in the answer key from Soares' study. Then to ensure that grading was unbiased, the answers that were not perfect matches were examined for correctness by a researcher who was unaware of the condition under which the tests were taken (i.e. whether the participant had the Fidgetato or not when taking the test). The final score for the test was then computed adding the perfect answers with the acceptable answers.

5.3.5 Attitude Towards Fidgeting Questionnaire

At the end of the study, participants were asked to fill out a short questionnaire about their opinion of fidget devices, as well as their opinions about fidgeting and attention. The purpose of this questionnaire was to see if people with positive views towards fidgeting performed better while fidgeting. See Figure 5.3 for sample questions or the appendix for the questionnaire in full.

I have a positive view of fidgeting and fidgets. 1. Strongly disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly agree
Using a fidget device might help me focus in class. 1. Strongly disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly agree

Figure 5.3: Attitude Towards Fidgeting Questionnaire Sample Questions.

5.4 Fidgetato Data Handling

The *Fidgetato* tracked button, clicker, and pressure sensor interactions during the part of the study that each participant was assigned to use it. Once turned on, the *Fidgetato* only writes data to a text file if something occurs. For example, the first three lines of data in Table 5.2 show examples of possible lines reflecting that the pressure on the pressure sensor changed. The fourth line of data shows that Button 1 is depressed and the fifth line shows that Button 1 was released. Both lines 4 and 5 also show changes in pressure on the pressure senor. Line 6 shows an example of what is written when the clicker is pressed, with line 7 showing an example of what is written

Datatime	Unixtime	ms	Rocker	B1	B2	B3	B4	ButtonByte	lbs
18:55:43	1636829743	3746	1	1	1	1	1	11111	0.0
18:56:01	1636829761	21744	1	1	1	1	1	1111	0.7
18:56:01	1636829761	21846	1	1	1	1	1	1111	1.4
18:56:01	1636829761	21897	1	0	1	1	1	1011	1.5
18:56:01	1636829761	22128	1	1	1	1	1	11111	0.9
18:56:05	1636829765	26171	0	1	1	1	1	11111	0.1
18:56:09	1636829769	30060	1	1	1	1	1	11111	0.1

Table 5.2: Sample of Data Output

when the clicker is returned to its starting state.

Due to the way in which the *Fidgetato* records interactions, the file size is not constant, but rather reflects the number of interactions that the participant has with the fidget. This can result in thousands of lines of data. In order to process the data, a python program summarizes each participant's interactions in the following way: Number of Interactions during the video, Number of Interactions after the video, Number of Clicker Interactions (pressing the clicker is equal to one interaction), Number of Button Interactions (pressing and releasing any of the buttons is equal to one interaction), Number of Squeezes, and Max Pounds of Pressure on Pressure Sensor.

The Number of Clicker Interactions is incremented by one each time the clicker changes state (i.e. goes from a 1 to a 0 or from a 0 to a 1) while the Number of Button Interactions is incremented by one for every two changes of state (i.e. from 1 to 0 back to 1). Hence, the data snippet in Table 5.2 would result in: Number of Clicker Interactions = 2 and Number of Button Interactions = 1. The Number of Squeezes reflected in Table 5.2 is 1. This is because squeezes are counted every time a change from increasing to decreasing values is noticed in the lbs column. An example of one complete data file from one of the participants can be found in the appendix.

5.5 Results

5.5.1 Memory Test Performance

In order to address my primary question for this study of whether or not fidgeting with the *Fidgetato* would cause a memory impairment, Dr. Soares ran the same statistical analysis that she did in her fidget spinner study. She conducted a paired-samples t-test on the data for performance on the memory test. This test indicated no evidence of a difference in performance between the conditions in which participants used a fidget and did not use a fidget, $t(51) = 0.134$, $p = .894$, $d = 0.02$, CI95% of d = [-0.25, 0.29]. She calculated the Bayes factor for odds in favor of the null hypothesis (scaled JZS Bayes Factor, Jeffrey-Zellner-Siow Prior) and found the likelihood that there was no memory impairment caused from using the fidget was 9.12 times more likely than that there was an effect that was not detected. Statistically, this is considered moderate-strong evidence that the findings of no memory impairment are correct.

5.5.2 Metacognitive Estimates

The same analyses were conducted for the metacognitive estimates, the self-reported estimates of how well participants thought they would do on a fill-in-the-blank

I noticed myself mind-wandering about things UNRELATED to the video

1. Never
2. Rarely
3. Sometimes
4. Often
5. Very often

Figure 5.4: Example of participant answer valuation.

test. The paired-samples t-test on the metacognitive estimates data also indicated no evidence of a difference between the two fidget conditions, t(50) = 0.679, p = .501, d = 0.09, CI95% of d = [-0.18, 0.37]. The Bayes Factor for odds in favor of the null hypothesis found the likelihood that participant's metacognitive estimates were unaffected by fidgeting was 7.35 times more likely than that fidgeting impaired participants metacognitive estimates. Statistically, this is considered moderate evidence that the findings of no metacognitive impairment due to fidgeting is correct.

5.5.3 Attentional Lapses

For the attentional lapses survey data, responses were transformed into numbers ranging from 1-5 corresponding with the Likert scale included in the survey. Higher numbers corresponded with numbers indicating higher attentional lapses. As an example, the answer "Often" in the attentional lapses question in Figure 5.4 would result in a score of 4.

	Memory	Metacog-nitive	Mind-wander	# Inter-actions	# Clicker Clicks	# Button Presses	# Squeezes	Max lbs.
Memory	1							
Metacognitive	**0.407***	1						
Mindwander	-0.186	**-0.395***	1					
# Interactions	0.098	-0.026	**0.319***	1				
# Clicker	0.027	-0.069	**0.374***	**0.519***	1			
# Button	-0.04	0.011	0.126	**0.624***	0.252	1		
# Squeezes	-0.075	-0.046	0.188	**0.719***	**0.386***	**0.937***	1	
# Max lbs.	0.06	-0.054	0.261	**0.522***	**0.349***	0.046	0.167	1

Table 5.3: Matrix of Bivariate Correlations: * denotes statistical significance with p 0.05

Using these numbered equivalents, a mean was calculated for each participant excluding the question about thoughts related to the videos they watched, and these means were analyzed using the same paired-samples t-test and Bayes odds analyses. No evidence of differences in attentional lapses were found between the two experimental conditions, t(51) = 0.134, p = .311, d = 0.142, CI95% of d = [-0.13, 0.41], Bayes factor = 7.27; moderate.

5.5.4 Fidgetato data

Bivariate correlations were conducted between the cognitive measures and the summary of the measures collected by Fidgetato (see Table 5.3). Generally, different kinds of interactions with the fidget were positively correlated with one another. Interactions with the fidget were not significantly correlated with the memory or metacognitive measures. There was, however, a positive correlation between overall number of tracked interactions and reports of attentional lapses. This correlation seemed to be most strongly driven by the use of the clicker on the device.

5.6 Discussion

5.6.1 Is the memory impairment associated with Fidget Spinner use present with all fidgets?

My study found no evidence of a difference in performance with and without the Fidgetato, leading to the conclusion that there is no memory impairment associated with its use. Given that several studies identified a performance deficit with the use of Fidget Spinners, I conclude that not all fidgets are the same, and that care must be taken when designing and/or choosing fidgets and other tangibles so as not to create an impairment.

5.6.2 Does fidgeting alter participants' expectations of performance?

The data found that the metacognitive estimates were unaffected by whether or not the participant was fidgeting. This is interesting in that even when the data was analyzed taking into consideration whether the participant had positive or negative views on fidgets and fidgeting, there was still no evidence of a change in their ability to accurately estimate future performance on the memory test with and without the fidget. I was interested in this because my hypothesis was that people with positive views might exhibit unfounded optimism about their grasp of the subject matter when using a fidget. But this was not the case. Whether the participant held positive or negative views on fidgets and fidgeting, there was no evidence that fidgeting impaired participants' metacognitive estimates.

5.6.3 Does fidgeting impair focus?

A significant positive correlation between reports of attentional lapses and the overall number of tracked interactions (see Table 5.3) was identified. I cannot draw any causal inferences from this because this correlation could be due to any of the following: 1) participants might have noticed that their mind was wandering and fidgeted more to try to be more present or focused, 2) participants might have remembered that they interacted with the fidget a lot and thought that they must by association have been mind wandering, and 3) participants might have fidgeted more thus causing more mind wandering.

5.6.4 Does the amount of fidgeting affect performance?

Unlike the Fidget Spinner study, which only noted that participants held the spinner and not if they actually used it, due to the tracking capability of the smart fidget object, I was able to see how they interacted with the *Fidgetato*, both during the time they were required to hold it, and also afterwards, when they were free to put it down if they so chose. This tracking data enabled me to see if there was a correlation between usage and performance on the Fill-in-the-Blank memory test and metacognitive estimate. Analysis found no significant correlation between how much a participant fidgeted and how well they performed. It was interesting to see the patterns of usage. While outside of the scope of this study, further investigation could be done to see if different tasks prompted different fidgeting interactions.

It should be noted that while the *Fidgetato* tracks pressing, clicking, squeezing, and even exerting force on the pressure sensor through rubbing as some participants were witnessed doing, it does not have the ability to track all interactions. Some participants were seen rubbing, most often up and down the groves on the front, and spinning the *Fidgetato*. These interactions were not tracked and would have resulted in a higher interaction count.

5.6.5 Other observations

Interestingly, several participants who did not interact at all with the *Fidgetato* during the study, seeming to choose to hold it in such a way as to touch it as little as possible during the video, and putting it down immediately once the video ended, chose to pick it up after the study and fidget with it continuously while talking with the researchers about the study, even when the subject changed to conversations unrelated to the study. This might have happened due to the participants being more familiar with the object at that point. It is possible that if the participants were given a longer amount of time to get acquainted with the *Fidgetato* prior to the study, enough time to make interacting with it more routine, they might have interacted with it more, and perhaps then some benefits from use might have been discernible.

5.7 Conclusion

Previous studies found memory impairments associated with fidget spinner use during cognitively demanding activities. I was curious if the memory impairment identified in those studies extended to all fidgets, so I replicated the test from one of the studies [40] using a fidget object that my previous research indicated (see Chapter 2) might lend itself more to learning activities. I used the *Fidgetato* (see Chapter 3 for design and testing of this device), an electronic fidget object with the ability to track and record participant pressing, clicking, and squeezing interactions. Based on the data from my study, a memory impairment is not associated with using the Fidgetato during cognitively demanding activities. This answers my initial question of whether or not the memory impairment identified in fidget spinners extends to all fidget objects and definitely raises the possibility that the memory impairment found by previous researchers is specific to fidget spinners.

This is promising in the context of the literature in that the *Fidgetato* is not causing the same kind of impairment that a fidget spinner did. The implication of this is that not all fidget objects are created equal.

For the general public, the results indicate that beyond fidget spinners, there is no proven need to discourage fidgeting in a classroom or work setting – at least with the *Fidgetato*. There even exists the possibility that the memory impairment is solely associated with fidget spinners and as such, only fidget spinner use should be limited.

Future studies could investigate whether more familiarity with the *Fidgetato* would make fidgeting with it less a novelty and more routine, which could possibly lead to focus and retention enhancements. It is possible that focus and retention will remain unaffected even with more familiarity with the *Fidgetato*, leading to studies aimed at identifying common characteristics of people who performed better using the *Fidgetato* or studies attempting to identify any possible self-regulation benefits from use.

As designers of fidgets and other tangible objects, this work suggests that we need to be mindful that the affects of using different fidget objects are not the same and make sure that the objects that we create are not adversely affecting users. These results may be of value to community members focused on tangible user interfaces, as well as those working in the domain of self-regulation.

Chapter 6

Conclusion and Future Work

6.1 Summary

This dissertation discusses the research involved in designing, building, and validating a tool created to investigate how technology could aid in understanding fidgeting. The driving questions of this work were: 1) How can technology improve our understanding of fidgeting? 2) Can I make a device that tracks fidgeting interactions? 3) What are the appropriate affordances to incorporate in such a smart device? 4)What is an appropriate design for such a smart fidget device? 5) How can I validate this device? and 6)What new insights can I obtain by utilizing this device for research studies on fidgeting?

First, in order to gather information to aid in the design of the smart fidget, I have presented a five stage study into children's fidgeting. This study identified children's material, form factor, and inherent interaction fidget object preferences. In addition, it uncovered relationships between several interactions and various activities or emotional states. My study on children's fidget object preferences [10] was well received at the Designing Interactions Conference. In addition to aiding me in the design of the smart fidget, another researcher in my lab leaned on the insights obtained in my fidgeting preferences study to design and build two other smart fidgets [37, 39], further confirming that the results of this study can be used to guide designers of fidgets and other hand-held tangibles.

Next, I discussed the creation of the smart fidget, the *Fidgetato*. This chapter detailed the design, creation, testing, and minor alteration of the *Fidgetato*. At the onset of my design process, it was clear that it would be impossible to make one object that would be considered "perfect" for everyone, so instead I aimed to make an object that the majority of people would gravitate towards and want to interact with. Preliminary testing for data capture and comfort/attractiveness/usability indicated that my design accomplished my goals and that this self tracking fidget object (*Fidgetato*) was serviceable for my purposes.

Subsequently, I presented my analysis of an online data set. Due to Covid and my inability to test conduct in-person tests with the *Fidgetato*, I had to pivot and adjust my research plans. Consequently, I chose to analyze a pre-existing online data set that contained hundreds of fidget object submissions. The nature of the online data set made it possible that participants could decide to opt out if they saw submissions that contained objects similar to their own. Due to this, I was unable to form ideas about the percentages of the population that engages with each of the categories of objects that I found. However, given the sheer number of submissions, this data set was a wonderful source for ascertaining the breadth of fidget object interactions and motivations. This information could serve designers and researchers by providing different avenues to explore in the future.

Finally, I discuss a fidgeting study that I ran using the *Fidgetato* in order to validate its design and utility as a research tool. This study investigated whether or not fidgeting impacts performance on cognitively demanding activities. As I hoped, the *Fidgetato* held up to the rigors of testing by providing real time usage data. This data enabled me to see how people were actually interacting with the fidget object, rather then just relying on participants' recollections of fidgeting or the limited information on fidgeting interactions that can be recorded during a fly-on-the-wall type study. By having this level of information on usage, questions related to usage were answered, such as whether or not fidgeting with the object more impacted the participant differently than fidgeting with the object less.

My key findings from this work are that not only can technology provide more accurate data on when and how people fidget by instrumenting their preferred interactions with a smart fidget device capable of tracking their fidgeting behavior, but that the resultant data can lead to deeper insights on fidgeting and its impacts than can be obtained with traditional methodologies like fly-on-the-wall observations or after the fact interviews and questionnaires. This is due to the detailed data stream created during testing, which conveys when each of the interactions are being performed. This timestamped log of fidgeting activity allowed me to analyze usage patterns to see if varying usage affected performance during cognitive activities.

While validating the suitability of the *Fidgetato* for research purposes, I found that fidgeting with the *Fidgetato* did not negatively impact focus and retention during cognitively demanding activities. Due to the detailed interaction log for each participant, I was also able to answer questions related to usage. Consequently, I found that changes in frequency of use (how often or fast someone fidgeted with the smart fidget) or fidgeting interaction did not alter the findings. In addition, the majority of my study participants found the *Fidgetato* appealing due to its affordances for clicking and pressing. This finding validated the decision to incorporate them into the design, since their inclusion helped me meet my design goal of creating a smart fidget that would appeal to the majority of people.

In conclusion, this tool should be useful to the research community studying fidgeting. Further, the findings related to fidgeting preferences in terms of interactions and material qualities, identified relationships between certain emotions or activities and particular fidgeting interactions, and lack of memory impairment when engaged in certain interactions should be helpful and relevant specifically to people in the area of tangibles and computing in Human Computer Interaction, by leading the way for designing instrumented fidgets. This information should also prove useful for those who are trying to create tangibles for other purposes.

6.2 Future Work

Of course, many questions remain in the area of fidgeting and fidget tracking devices. Possible future directions for this work could include having an app that displays a person's fidgeting behavior for the week which could provide them the ability to modify or reflect on that behavior. Another possible future direction would be to investigate anger or stress management at work by analyzing fidgeting patterns in that setting.

Another possible future directions would be to conduct longitudinal studies. A lot of times short term studies get criticized because there is a novelty effect with new technology. If people have the device for longer then we might see different results than I found in my cognitive study.

In parallel, future work will revolve around making the smart fidget smaller while increasing the types of interactions it can track. For instance possibly incorporating a flexible outer shell so that squeezing any part of the fidget device will result in tracking data.

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