UNIVERSITÉ
PARIS
SUD

Master 2 in Computer Science - Interaction Specialty

Bimanual Tools for Creativity

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March 1, 2020 – August 31, 2020

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Summary

This project explores the implications of designing for creativity, especially the earlier stages of the creative process involving inspiration and serendipity. The rich HCI literature on bimanual tools is leveraged to design tools that support the embodied nature of creativity. The various definitions of creativity in HCI and psychology are explored, with new perspectives on embodied creativity introduced from neuroscience. In the first study, user experiences of the creative process are collected, and generate three themes and five sub-themes with implications for design. From these user stories and theory, a research through design approach is taken to generate artifacts to explore these themes. This concludes with three technology probes to explore a design space of bimanual creativity tools. The second study uses these three probes to generate new user experiences and novel design insights. This suggests new directions and implications for designing bimanual creativity tools, and also generally designing for creativity, serendipity, and embodied thought.

Keywords

creativity, creativity support tools, serendipity, embodiment, bimanual interaction, bimanual tools

Introduction

Creativity is an exciting and hot area of HCI research, and the goals of this work are to probe that area further, while at the same time tying into it the potential of the deep well of HCI knowledge and research about bimanual interaction.

Creativity support tools, and the evaluation of this type of technology is an area of increasing interest to the HCI community. Additionally, designing for creativity presents a variety of exciting new challenges, particularly, how can technology be designed to support a process that may not have a clear means or goal in mind? This contradictory tool would have to be designed to support tasks that it is not necessarily designed for, yet this is important because some of the most interesting and creative ideas come out of using software in ways it was not designed for, and yet ways it was left open to be used [105]. While there are plenty of tools and software that are designed with creative intent, the vast majority of this is targeted at the later, production phases of the creative process, and not towards finding inspiration and the earlier stages of the creative process. In short, this project is about discovering how serendipitous encounters can become a design goal of technology and human-computer interactions.

From this HCI-centered view of creativity, I introduce some new ideas about embodied creativity from neuroscience and psychology, that are only just starting to be noticed by HCI. This provides a transition to beginning to imagine physical tools that support the early stages of the creative process through bodily engagement. These tools connect to the large reservoir of knowledge about bimanual tools in HCI, but a reservoir that is critically dry in terms of tools oriented to creativity and not classical productivity. Designing bimanual tools for creativity becomes the main focus of this research. This more open ended bimanual tool allowed an exploration and connection to fidget devices, and other "self-regulation" toys that people play with while working to maintain focus. Based on the embodied creativity literature, this type of self-regulation should also apply to engaging the brain in increased creative productivity.

This project begins at a very basic level, asking what is creativity in practice, and exploring the stories of different professionals' creative processes. These stories help to elucidate the key stages of the creative process across disciplines, and ultimately crystallize a more concrete understanding of what is meant by serendipity and inspiration. From here, I take a research through design approach to generate artifacts, based on both the user stories and theory, to further explore designing bimanual tools for creativity. This starts with simple experiments in form for bimanual fidget and productivity tools. This expands into some collaborative ideation stages, ultimately working towards a video prototype to examine a bimanual creativity tool, in-situ. From these divergent stages, a design space is mapped, with the themes and theory as guide, and then explored deeper using three technology probes. The project finishes with a study of these three probes, to find new experiences and generate new insights about designing for embodied creativity, bimanual interaction and serendipity. The stories and experiences from these probes illuminate new directions and insights for designing for bimanual creativity tools. These findings also suggest how HCI can aim to support embodied creativity, and serendipity more generally.

Related Work

2.1 Creativity

HCI researchers still struggle to define creativity [42, 93], let alone serendipity and inspiration, and so I turn to the arts, where poetry and metaphor allow us to get closer to these definition than any other way. An insightful definition of creativity and inspiration comes from Greek myth of the nine muses:

> The Muses are the Greek goddesses of poetic inspiration, the deities of song, dance, and memory, on whose mercy creativity, wisdom and insight all depend. They are born in Pieria at the foot of Mount Olympus, the daughters of Zeus and the Titaness Mnemosyne, Goddess of Memory [27].

This story captures a crucial aspect of creativity and insight – they are the offspring of memory. The successful creative individual draws upon memory, their own and a collective human knowledge [62], to combine ideas and sources in new ways. Just as the Muses are literally the offspring of memory, so to are inspiration and creativity. Creativity is quite literally the progeny of memory.

Serendipity is also easiest explained through myth of The Three Princes of Serendip:

> King Giaffer of the ancient kingdom of Serendippo banishes his sons in an effort to teach them to be more worldly. In their travels they pick up the tracks of a camel, and noticing small clues, deduce he is blind in one eye, missing a tooth, lame, carrying a pregnant woman, and buckets of honey and butter on its sides. They encounter a merchant who has lost this camel, and hearing their description, he reports them to the Emperor for stealing. They explain their deduction: the grass is eaten on only one side of the road, chewed unevenly, uneven tracks, footprints, and signs of the different insects that are attracted to either butter or honey. And when a traveller comes to report a found camel, the Emperor appoints the princes his advisors. Many adventures follow, and they live happily ever after. [55].

"Serendipity" was coined by one Horace Walpole referencing this story in a letter from 1754 [66], to captures this feeling of accidental discovery that is crucial to inspiration. But, how to design for an experience which you are not aiming to have? And if you aim to have you will not have? This continues to fascinate researchers in diverse disciplines [66], not least HCI.

There are essentially two solutions to designing serendipitous encounters. The first is to deconstruct "serendipity" as a series of achievable steps [3], thus experiences can be designed, with chance meticulously introduced at the appropriate stages, to inspire "serendipity" [28, 3, 38]. Crucial to this solution is the idea that creativity is an associative exercise [78]. The second, less common approach is to design tools with a specific use, but that invite unexpected uses. For example, an art installation designed to encourage chance encounters [26], CAD tools that retain some of the natural randomness of human drawings [46, 85], or using PowerPoint to build a Turing machine [105].

2.2   Creativity and Technology

This brings us to where creativity and technology meet in Creativity Support Tools (CSTs), where HCI is a leading field. Several reviews are useful as indicators of where this research has been, and where it has yet to go.

The need for creativity research in HCI is a real one, especially as expectations of creativity grow across society, and evolve from old systems of knowledge when scholars primarily translated and transcribed [93]. There are three main schools of creative thought. The structuralists hold that creativity is a set of steps anyone can follow. The inspirationalists take a more whimsical view that creative solutions arise through breaking routine and serendipity. Finally, the situationalists hold that creativity is situational – the product of interactions [93]. From this final perspective, creativity is about context and relations; structuralism and inspirationalism are stages in this process [24, 25]. From these arise four key design principles: exploratory search, collaboration, rich history, and "low threshold, high ceiling, wide walls" [93]. This leads to the question of evaluation methods, a recurring challenge to HCI research. Classical experiments can't capture the creative process; "multi-dimensional, in-depth, long-term case studies" are required [95]. This also helps to begin a re-framing of the terminology of success for creative systems, away from classical terms derived from a work-oriented view [16, 76]. This question of terminology arises again in the *Bimanual Interaction* section.

Two recent related reviews show some of the shortcomings of CST research, and attempt to remedy some of them. One key problem is a lack of a definition [42] – over 100 definitions for creativity have been proposed [101]. The two most influential models of the creative process from psychology are then proposed for HCI [41]: Amabile's four-stage model – identification, preparation, generation and validation/communication [1], and Runco and Chad's simplified model that does away with preparation [89]. This is based on a historical understanding of how creativity research has evolved. The "first wave" begins with the American Psychology Association in the 1950s, and studies of convergent and divergent thinking. A "second wave" begins in the 1980s, when focus turns to the interdisciplinary and collaborative nature of creativity. Finally, we have entered a "third wave", where digitization and tools have become the focus of the research [41]. HCI research has remained stuck in the second wave, despite work showing the benefits of ideating alone [20, 73], and has been misled by this third wave, studying new tools "in-vitro" as oppose to how tools are used "in-vivo" [42].

As this field has evolved, a wealth of design guidelines have been proposed to guide CSTs [50, 87, 90, 94, 93]. In a single phrase, these could all be summed up by "low threshold, high ceiling, and wide walls" [87, 94, 93] – allow easy immersion, with features that allow experts to grow, with a wide range of possibilities to explore.

Evaluating Creativity

The main challenge to creativity research remains evaluating CSTs, when usability evaluations do not work, and an error may instead be serendipity [17]. Most critics lean towards a process view of creativity, and advise evaluating using longer-term, in-depth studies [42, 41, 94, 93], yet fail to indicate how to measure creativity in that time. Most research however, measures creativity as a trait.

The earliest tests come from 1960s psychology [5, 100, 22], and have changed little [9]. Versions of these tests have been appropriated across a wide range of HCI, to evaluate creative solutions in mathematics [75, 74], programming [43, 70, 77], video games [11], engineering [92] and information visualization [60]. Combining these tests is one attempt at better accuracy [81]. HCI-specific indexes are another way of measuring this trait: from the Creativity Support Index, inspired by the NASA-TLX questionnaire [18]; to the Creativity Product Semantic Scale [82], which evaluates novelty; to the Epstein Creative Competencies Inventory [35], which aims to predict creative output.

A process view of creativity involves evaluating the creative products users create. Again there are a range of solutions: click-through metrics of web ads [34], AI judging [97], protocol analysis [68], case studies [84], qualitative observations and interviews [49, 56], self-reporting [102, 108], quantifying ideas [71, 88], and pairwise ratings [34]. Some noteworthy techniques use algorithms, based on associative creativity [48, 78, 79] and design theory [92], to calculate a creativity score for user-generated content [60, 67, 92], or track GSR/EEG signals to measure creative arousal [19]. However, in most cases, these methods are supplemented with expert creativity judging.

In summary, evaluating creativity is still largely based in the 1960s [5, 48, 100]. New methods have arisen, but are largely supported by expert judges [54].

2.3   Embodiment

An important direction of creativity research in psychology and neuroscience, yet to reach HCI, is the relationship between embodied cognition and creativity. Embodiment is a cornerstone of the current wave of HCI literature [32], which provides a basis for this connection, and has been studied in the work place, but this has been limited to a narrow view of productivity, not creativity [21]. Embodied cognition can be distilled into six pieces [107]: 1) cognition is environment-situated, 2) cognition is time pressured based on environmental interactions, 3) cognitive load can be lightened by offloading to the surroundings [69], 4) the information flow between mind and environment becomes too thick to be distinguishable, 5) cognition's function is action, so perception and memory are in relation to actions, and 6) even when engaged in abstract cognition, brain activity is grounded in environment-based, sensorimotor functions [31, 98].

Attempts to update HCI definitions and evaluations of creativity [90] connect to the latest research in psychology and neuroscience, connecting body, brain and creativity [29]. Based on this research, [90] proposes a model of creativity that captures deliberate and spontaneous attention changes, different types of knowledge used (emotional or cognitive), and the changes in the prefrontal cortex (PFC) as thoughts are conceived, processed and implemented. This map of creativity helps connect movement that activate the PFC to creative thought. This role of movement has been shown to help understanding and create meaning in classrooms [45]. Even the smallest movements, such as bilateral eye movements, can stimulate "inter-hemispheric interaction" in the brain and increase measures of creativity [96].

Walking is another very well documented way of moving to activate the brain [59]. From improving memory [36, 37, 80, 91], attention span [99], and brain activity [12, 63, 103], to directly boosting creativity [6, 30, 81].

Fidget Widgets

Connecting movement, thought, and creativity, Karlesky and Isbister describe this type of interaction as "embodied self-regulation" [65], a process to redirect spontaneous thoughts to increase focus, creativity, and motivation. Embodied processes – or fidgeting – to self-regulate has a basis in psychology: various fidgeting patterns – or "task unrelated thoughts" – help to prevent "goal habituation," and enhance focus [4, 39]. Doodling has also been shown to positively impact memory [2]. In HCI, desk toys for playing and focusing while using computers have been catalogued, and tested [64]; haptic features of mobile phones have been used to replicate fidget spinners[1] [106]; and a stylus has been designed [13] to explore the relationship between stress and fidgeting [39, 90].

Procrastinating is another side of "task unrelated thoughts." While little HCI research has probed this, it is an important part of the creative process. In his guide on creative thought, John Cleese calls this "succumbing to the unconscious mind" [23], and Isaacson notes that Leonardo da Vinci was one of the greatest procrastinators of all time, and one of the most creative geniuses [58].

2.4 Bimanual Interaction

Based on a desire to support creativity, and the ideas of embodiment, it is natural to turn towards the existing HCI research in bimanual interaction. This is a deep well of HCI knowledge, that has long sought to return some of our more natural movements to our desktop interactions [50, 83]. Guiard's kinematic chain model explains why these interactions are more natural [47]. His work shows that there is no such thing as a unimanual action, rather all actions use both hands and pass through this "chain": input comes to the non-dominant hand, moves to the dominant hand, and finally to an output.

Despite the embodied nature of creativity, HCI has only focused on using bimanual interactions to lighten cognitive load, to increase speed and efficiency in completing tasks. This has covered a range of applications: from drawing software [8, 14, 40, 83, 72, 104], to office information systems [14], to modern smart-phone and mobile interactions [52, 86], map applications [51], and even medicine [53]. In general this work builds on the idea of "chunking" [15], where multiple low-level interactions can be chunked into a single higher-level action. Combined with Guiard, these two ideas guide this work on coordinating activity between the hands to increase efficiency.

Some of this work has shifted slightly away from productivity, to explore the cognitive benefits of bimanual input [72, 83]. Owens et al. do draw a distinction between epistemic and pragmatic action [69], and the former begins to connect with creative modes of thinking [90]. Bevans is another an exception, who's research proposes that multi-touch interactions might increase creativity [7].

Despite these small exceptions, HCI remains focused on using bimanual interaction to optimize performance in a classical office-task framework. Meanwhile, the modern wave of HCI is redefining the conditions of good use, and usability, no longer confined to efficiency and error-free performance [76]. It is within this vein that I situate my work exploring how bimanual interaction may have creative benefits beyond speeding up task completion and lightening cognitive load.

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[1]https://en.wikipedia.org/wiki/Fidget_spinner

Study 1 - Stories of Creativity

3.1 Study Design

The goal of the first study was to collect lived experiences of the creative process. I was especially interested in this process, overcoming creative blocks, finding inspirations and solutions, and the role that procrastination plays. Interviews were conducted, and supplemented by stories collected from several online communities dedicated to creative arts. This provided a wider base of data to support the themes that arose from the interviews.

Participants

Seven creative professionals, from visual and audio arts, participated in the interviews. They were generally multidisciplinary and worked across a variety of disciplines: three musicians, four music producers, four digital artists, two illustrators, two graphic designers, one painter, and one architect. They ranged in ages from 24 to 32, and came from or lived in, France, Canada, the United States, Germany, the Netherlands, Finland, China and the United Kingdom.

From Reddit, I collected stories from five subreddits: r/freelance (151,000 members), r/graphic_design (435,000), r/ArtistLounge (59,000), r/Screenwriting (777,000), and r/AskReddit (29 million). I collected comments or threads from 55 unique Reddit users.

Procedure

Interviews took approximately one hour, including a brief introduction to my work and consent for recording audio. The semi-structured interview focused on stories of recent projects, and finished with some targeted questions about creative habits and workspaces.

To collect Reddit stories, I searched across the aforementioned subreddits with a variety of search terms and combinations thereof: creativity, creative, procrastination, deadline, block, stagnation, inspiration, and workspace. In addition to this, I received daily email updates from Reddit, which I skimmed for interesting or active posts in the creative subreddits I followed. I saved and followed any post that had hints of my own questions within it.

Apparatus

COVID-19 restrictions meant interviews had to be conducted on video calls. Most participants were working from home, so having calls take place in their homes offered a chance to explore their home office setups.

Data Collection

From the interviews I took handwritten notes, and transcribed audio recordings. I saved relevant comments and threads from Reddit. All these stories were collected from posts within the last year, with two exceptions from four and seven years ago.

Analysis

To analyze this qualitative data, I conducted a thematic analysis as suggested by Braun and Clark [10]. I began with an inductive approach to crystallize an initial set of themes, and gradually shifted to a combined inductive/deductive approach to find new themes, but also find commonalities between the diverse experiences. Codes were developed and discussed with other members of the research team, and slowly shaped into an initial set of themes, which went through further iterations to arrive at the final set of themes below. I combed through Reddit stories, looking for comments with these different codes and themes. Based on the final themes, additional passes were done over the data to see if further experiences were in concert or contrast with those themes.

The data was collected from a variety of creative mediums, which provided a unique opportunity to pull common threads between disciplines, where slight differences or preferences help to illuminate larger commonalities and themes.

3.2 Results & Discussion

The thematic analysis of the interviews revealed three themes and five sub-themes: *The Signature Toolbox*; *Mindfuck Mindset*, with sub-themes *Angry? Anxious? Creative!* and *Breaks*; and Manufactured *Obstacles*, with sub-themes *Speed, Working with Others*, and *Speed Bumps*.

I collected 31 stories from 55 Reddit posts: six for *The Signature Toolbox*; 10 for *Mindfuck Mindset* plus one for *Angry? Anxious? Creative!* and seven for *Breaks*; and three for *Speed*, and 4 for *Working with Others*.

Theme 1: The Signature Toolbox

The idea of the signature toolbox has two components: creative work is a product of the tools used, and nothing comes from nothing.

In the first case, the tools used determine creatives' work to such a degree that developing a "personal toolbox" becomes an integral part of the process. This idea was most clear with two of the music producers, P1 and P4, who spend a large amount of time and energy managing and curating an archive of sounds they can turn to for inspiration. This takes on a new importance, because once you have your own tools – have spent time creating a high quality toolbox – you develop a signature sound that creates quality work, and marks it as yours. P1 was in an early stage of a career, so very consciously developing this toolbox to find a signature sound, while P4 was more experienced, and quite proud to share his toolbox and system for organizing sounds, though its always a work in progress – he knows people with more sophisticated systems and "I don't do this as hardcore as what I should."

The other side of this idea is that nothing starts from nothing – everyone uses sources – which was likely the largest commonality across every participant. This also returns to the idea of serendipity – much of the work in finding inspiration involves an encounter to begin the process. This toolbox performs a second function as a source to trigger inspirational encounters. P1, 2, 4, 6 and 7 kept archives of their work and others' to quickly turn to when starting a project. Often this is taken a step further, and the toolbox holds templates to get ideas started as quickly and friction-free as possible.

While most interviewees kept collections, differences arose in how this was filled. Similar to templates, reusing old work from this archive is common, so creating work "even if it sucks," is still a good practice, and helps develop this archive. It is also helpful to visit places where inspiration can be gathered, both physical spaces – "landscapes," "music festivals," or "museums" – and imaginary ones: stories, anecdotes, or "specific" TV shows and movies. Finally, there are virtual spaces dedicated to collecting, like Instagram, Pinterest or Behance. P3 had a "daily habit" of browsing these sites, "not purposefully, its just randomly browsing, and let me see any other things." P6 had set up Reddit to function in a similar curated way, "I get some very niche music subreddits... So I might discover some new music, some new ideas." Beyond seeking out these spaces, eventually creatives become tuned to collect inspiration anywhere, for example, P4 had recently added the clicking sound of the Netflix browse-scroll to his sample collection.

Theme 2: Mindfuck Mindset

The second theme turns towards the mindset you must find to get creative. P4 explained this most succinctly: "you kind of have to mindfuck yourself." Getting inspiration flowing, and creativity producing, is rarely easy, and people who need to be creative must develop techniques to trick themselves into this mindset. Much of this involves setting yourself up for inspiration to strike – a mindset that "creates happy accidents" (P4). How this mindset is achieved will never be exactly the same for two people, however, there are commonalities between techniques, and some common solutions.

Developing routines is one of the simplest ways of increasing your chances of finding inspiration or creativity. The most common routine is forcing yourself to create every day (P1, 4, 5, 6 and 7), which is doubly beneficial in helping to fill the signature toolbox. P2 explained how this recurring activity helped maintain a positive mindset, "the impression that I was working towards something and making progress... helped me avoid the feeling of despair." For P7, routines helped to avoid distractions, like working first thing in the morning "before even leaving bed," or very late when no one else is awake. Drawing before in bed in the morning also helps them to draw inspiration from dreams.

Play is another way of describing this mindset, and P5 and P6 talked about how easy it was to create when they could convince their mind they were playing. P6 had only stumbled into this, but P5 had built a workstation around a "perhaps unnecessary" piano to encourage playing, to trigger this state of mind. This idea of play is well documented in the concept of the flow state [24]. P4 also mentioned aspects of flow, such as a warping of time, and the importance of being present to make quality work.

Theme 2.1: Angry? Anxious? Creative!

In stark contrast to playing, common descriptions of this mindset involved feelings of frustration, anger, even anxiety and stress.

P1 was very aware of using anger to get creative, "I have to get a little pissed... I was taking a break for two weeks which pissed me off... then really, I was just creative." For P7, "I find I do my best work last minute... under pressure," so they developed a routine to create stress, "sometimes months in advance, I'm just thinking about it a lot and stressing myself out." P4 also talked about how anxiety and pressure help his work, "good art.. it has to come from a

place of... desperation." For P5, music production was frustrating, "profoundly unfair... in no other creative art are you expected to be able to produce a work and reproduce it live," but this was a crucial fuel for his creativity. P3 also was fueled by frustration, but knew these negative emotions could end their work too, "it was really frustrating... I was actually thinking about giving up several times." P2 used similar negative language, about fear, when talking about a recent project, "The fear was... there's no place for me to to add to innovate to this."

Theme 2.2: Breaks

Breaks and procrastination also play an important role inspiring this mindset, but also in providing relief when it is a struggle to find. Also, breaks can provide inspiration by engaging with the subconscious and allowing time for ideas to marinate.

P4 and P1 were both stuck on recent projects, but with time to "help free up the mind," they came back to their work and felt "just creative." P2 recognized the importance of these breaks, but struggled with delaying decisions, or as he put it "to be comfortable with the idea of not having an immediate goal." P6 was very comfortable with this waiting, "I figured I would revisit it again later." P6 and P1 also used collaborations to create breaks. P7, though primarily a drawing artist, appreciated how painting forces them to stop for drying, "I get halfway done and then I'll like come back to it, maybe even months later."

The other side of breaks is their ability to refresh, and rejuvenate. P7 talked about using personal projects as a break from commission pieces: "I take a couple hours and just draw for myself... and I get like a little refresh." P3 had a simpler approache, "for example take a cigarette," and really appreciated their balcony for short refresh breaks outside – especially working from home during the COVID-19 restrictions. P4 also talked about getting outside to refresh, specifically because of the stark contrast it provides to the dark music studios he is normally working in, "getting exercise and more so just like breathing...especially for somebody who...is like, majority of the time going to be inside and a fucking dark ass room, you know, like no windows." He described this feeling in a common way, "I need to clear my head," when he knows that stepping outside will help refresh, and refuel his creative productivity.

This refresh break can be both temporal or spatial, such as working for 2 weeks in Scotland. P2 talked about their most recent project, and how much motivation they'd found while staying in Scotland over the Christmas holidays, "I mostly did this over Christmas, I was in Scotland...I really want to add something to my project, I want to keep it alive, and the motivation was...this is the time where I'm gonna be able to do this." The COVID-19 restrictions also created a very strange break in space and time from normal life. P7 always appreciated isolation to be productive, "I live by myself...so I find that very helpful for me," and the quarantine had helped with this even more, "I was on a little bit of a hiatus...I finally am drawing again after like a couple months of not, so yeah, it was kind of like a boost."

One final important aspect of breaks is their potential to create time for an inspirational encounter, which connects to the theme of sources and serendipitous encounters. P4 explained that he sometimes cooks to get away from his work, but sees many similarities between making a recipe and a song, "famous chefs, just like a producer... they just started grabbing things that they know will go well together." P6 was recently inspired to create a project while taking a break listening to music, "This one song came up that I hadn't heard in a while...so I went to emulate that." They had also recently been inspired while procrastinating on Reddit, "Someone

was...saying like, Hey, I wanna collab and I could do lyrics and sing... I remembered, Oh yeah, I have this unreleased song that I could maybe fine tune a little and send to the guy." P7 had a similar experience, "I was procrastinating whenever I ended up doing that insole contest, so that was kind of cool."

Theme 3: Manufactured Obstacles

The final theme describes how creators manufacture obstacles for themselves to inspire or force creative solutions. While there are a range of techniques, they largely fall into three main sub-themes: Speed, Working with Others, and Speed Bumps.

Theme 3.1: Speed

Time limits are a common way to create artificial boundaries and constraints for creative work. Working with speed helps to push the creative process, and reduce concerns about quality. P1 often works on the train to force himself to finish within his commute, "You only have this 30 or 20 minutes timeframe so you really get stuff done... Also, these little bursts of, ok 20 minutes now in this space, get stuff done... that's really good to gather ideas." P4 had a similar conception of time as a boundary on bursts of creation, "I have to every single day sit down and make something from scratch... within 30 minutes, I know if it's a waste of time or I should keep going." P3 was stuck on a recent project, but finally used speed to force himself to get it done, "I promised to finish this in just one day." Similarly, P7 almost always finish projects in one go, "I usually bust out my drawing in one go...the first time I did that, it was maybe...10 straight hours of drawing."

Speed also manifests as an impatience with the process to get ideas down, "I just was impatiently, as quickly as possible, was trying to find a way to do this" (P2). For P7, they primarily draw, because "I can have like a finished piece after I'm done, like right away." P6 narrowed his composing to speed up the process, "I try the things out with one note first to kind of get the chord progression right...and if that works, then I can move forward." P3 used a lot of pen and paper in their digital illustration process because of its speed, "it just takes me maybe a couple minutes to have a rough idea," then "for some level of details I would come back to paper because that would iterate much faster."

Theme 3.2: Working with Others

Collaborations also help create obstacles by forcing dependencies on others' work, or creating a gap of understanding where the ideas for a project have to be clearly articulated, and understood. This provides new impetus for creativity, but also introduces many hurdles.

Sharing ideas was the most important part of P2's creative process, "Every time that I've ever had a breakthrough its involved somebody else's work or somebody else's idea." In fact, for him, "what it means to be creative I guess, is to set up a group of people who can help me." P7 also relied heavily on sharing work with her "mentors" – two more experienced artists: "I have an idea in my head, but I just kind of want to hear what they have to say." She also explained how sharing helps focus the direction of a project, "It was really easy to just bounce ideas off each other...instead of just having to decide for myself." She also felt the pressure of teamwork helps to move ideas along, "the idea usually comes pretty quick because... I have to be able to

like kind of delegate people pretty quickly." P4 also turned to collaborators when he was stuck, "We started bringing in other producers, for like, collaboration or like inspirational, you know, jump-start."

Working with others can also provide the impetus for a new project, such as P6, "We basically sent songs back and forth...he first sent me like this demo song...then I started building elements around it...Then the other way around." Similarly, P7 had recently created a lot of spray paint work, which was inspired by collaboration, "I kind of teamed up with two other artists for an installation at a festival and it was a lot of spray paint, so I had to learn and then I kind of fell in love with it."

Theme 3.3: Speed Bumps

The last obstacle connects to the ideas of frustration and creative mindset, and specifically how working slower can increase frustration, even stress, but some creators need this pressure. This is the opposite of the speed sub-theme, instead of pressures from time limits, pressure builds from working slower or even putting work off.

P7 talked a lot about how much she procrastinates and puts work off, "Generally I get the project, like I would say sometimes months in advance...then it usually comes down to a couple of days before." Yet, this actually functions as a tactic to create pressure, "I find I do my best work last minute, like under pressure." She often ends up procrastinating until the very last minute, but this works, "I usually pull all-nighters because then minimal distractions for me."

P5 also had a creative process rooted in slowing down. He had struggled with digital music production, "Making music by clicking and drawing...was un-intuitive to me, coming from a background in like classical and jazz piano where, where if I didn't get something right, I didn't click around to fix it, I practiced it more." To overcome this, he evolved a slower, more challenging production process, "this is kind of where the challenge comes in with like a, a partially digital, partially what feels like kind of analog workflow." But, this speed bump had only helped his productivity, "what I love about this is I've been able to write just so much music."

Design Process

The design process began with individual prototyping and exploration, which led into a collaborative stage, including two collaborative video sessions and some light-weight participatory design, and concluded with the fabrication of three technology probes. This process was heavily influenced by research through design [33], and ultimately the ideas of cultural probes [44] and technology probes [57]. Framed through this lens of research through design, the process was grounded in the theory from creativity, embodiment and bimanual interaction, and combined with the stories of creativity I gathered. From there I began to ideate, iterate, and generate artifacts for testing and critique.

4.1 Experiments in Form

Early on in this project I began to collect fidget objects. This began with various dedicated fidget devices, with switches, spinning wheels, sliders, dials, various textures, different buttons, and joysticks. From here, this went beyond objects designed for fidgeting, for example, Apple AirPods case[1], with their magnetic open-and-closing mechanism, and the scroll wheels in some computer mouses, specifically certain models that have a very pleasing weight. This was before COVID-19 restrictions went into effect, so these were given to some colleagues, and more examples were also collected from the toys on some colleagues' desks.

The first prototyping and fabrication started from this – I experimented making simple shapes that could help regulate attention, and/or function as a bimanual controller. These simple shapes generally didn't have the complex buttons of the fidget cubes, but in their simple forms they afforded various movements that could accomplish the same. I baked clay and salt dough into different forms to experiment with shape. I also collected various objects and materials that I could cut, bend, and shape into forms.

To get a feel for these shapes, I made annotations directly on their surfaces while using them (see: A.1). While writing early parts of this thesis, I fidgeted with these forms as I searched for the right words or ideas. Certain aspects were interesting, though many were not. I found that the simpler shapes were best, as more complex shapes felt prescribed and limited. This aligns well with the experiences in the lab with the dedicated fidget devices – even with the complex cubes, it was often the simplest texture or switch that was most interesting. Ultimately, experimenting and critically thinking about the forms of designs remained an important aspect throughout the design process.

4.2 Distributed Video Brainstorming

I began to collaboratively ideate at this point, and I conducted two rounds of collaborative video brainstorming to evolve the themes from the interviews into concrete interactions. This presented a methodological challenge as the COVID-19 restrictions prevented in-person collaboration.

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[1] https://www.apple.com/airpods/

However, I was fortunate to be able to use a collaborative web-based video editor, developed by Alexandre Battut, a colleague in the Exsitu lab. Using his tool, I ran two ideation sessions with participants based all over Europe.

Session 1 – Video Brainstorm

In the first session my goal was to gather as many divergent ideas as possible. To encourage this I refrained from enforcing too much framing. In hindsight, this was likely too little framing, which is addressed in the second session.

The session began with an introductory email two days before the session, outlining the schedule, design brief, and a short homework assignment. For homework, each of the five participants conducted a solo brainstorming session to come up with five ideas to share during the session. To frame this ideation, the design brief gave a short introduction to my research, with three design guidelines based on the interview themes and literature. Each guideline concluded with several open ended questions for brainstorming. The email also provided two URLS, for the collaborative video editor, and a video call link on Jistsi Meet[2], and a suggested list of materials for filming interactions. I intentionally called this list non-exhaustive to encourage participants to use whatever objects, toys or tools they might have on hand that lent themselves to specific interactions.

The session began with an introduction to the collaborative web tool, and setting up equipment: each participant needed a computer for the video call software and the video editor, as well as a smartphone with a camera connected to video editor. This was followed by a short summary and re-introduction of the design brief, then we shared the homework. While one participant acted as scribe, taking notes in the video editor, each person took it in turn to share their five ideas. This was intended to lead directly into selecting the top ideas and shooting quick videos. However, an unplanned but valuable part of the process was discussing, grouping and generating new ideas. The second session was framed to take much better advantage of this. After this we voted on our favorite ideas, then each picked one idea to shoot. After almost an hour of shooting, we regrouped in the video call, exported the videos and watched them all together. This led to further discussion of the ideas, as well as some reflections on the video tool, and the format of the session. The session was designed to be two hours, but ended up running for over three and a half.

The outcome was a wealth of ideas, across a wide range of fidget devices, productivity tools, and creative process ideas. This agglomeration of ideas pushed the limits of what I had been considering for tools to support the various stages of the creative process, and especially bimanual tools for productivity and fidgeting.

Session 2 - Video Prototyping

For the second iteration, my project had moved forward and my goals had shifted slightly. I had also learned from the previous session, and from participating in a colleague's session. The first session was stimulating, and a necessary step, but in the end the ideas were too divergent to move forward. I was also beginning to think about a video prototype to test these ideas of embodied creativity and bimanual tools in a scenario. While I didn't have a clear idea of this

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[2] https://meet.jit.si

tool, with rich profiles and stories from my interviews, I set up the session to directly target this goal. Focusing on what I concretely wanted to get out of the session, and how others' points of view could best contribute to my work, helped create a more directed, and fruitful session.

This session was framed to explore interaction points with three personas from the interviews, in a storyline that captured key creative processes I had found. The structure was much the same as the first session, with some adjustments. Each participant only brought three ideas to allow more time for discussion, and combining ideas. Additionally, after sharing all the ideas, and a quick discussion, we broke into two groups to have more in-depth discussions and begin shooting interaction points in two separate video calls. This was inspired by the a colleague's video brainstorm, where splitting into teams made discussions much more interesting, and shooting go smoother. After working in groups for around one hour, we regrouped in the main video call to watch the final videos.

The ideas from this session were much richer than the previous, which provided ample fodder for the next step of creating a video prototype. Also, the participants' feedback on the stricter framing of the brainstorm was much better than the first session. Reflecting on my own work, I can see how the personas and story provided a sort of manufactured obstacle that pushed participants to more creative solutions, much as my interviewees described.

Reflection

Moving to online collaborations for the ideation stages of the design process introduced some new challenges to this process. However, as I learned studying the creative process, obstacles are a key to fostering creativity and encouraging creative solutions.

At the highest level, moving talks to video calls made meetings more official – rather than bumping into someone, conversations have to be scheduled – but this forced me to reflect and articulate my ideas better. Once you are scheduling a call, it is hard to justify a call for only a couple minutes, and even harder to schedule a follow-up meeting if a thought strikes you after, rather than just sticking your head back into an office. Compounding this issue was scheduling times for multiple people, thus, once different colleague could find a time to meet, it was important to take full advantage of the time with extra minds focused on the project.

The largest hurdle I had at the beginning of these sessions was conveying the research I had done, and framing this in a design brief, when my early findings were neither concise nor clear yet. This is a natural part of the process, however, communication through email rather than face-to-face was a new challenge. The schedule of the virtual brainstorming allowed for a short presentation at the beginning, but this was largely relegated to the pre-session email, in order to maximize productive ideation time during the video call. This led to the structure of the second session with a clear narrative and several strong personas – virtual brainstorming needs very clear objectives. This is always a factor in brainstorming, yet has even more importance in the structure imposed by video calls, where communication is neither fast nor fluid, which clashes fundamentally with the atmosphere of a traditional brainstorm, where ideas fly fast and loose.

4.3   Video Prototype

Following the brainstorms, I needed to pull all the ideas together into some cohesive design. A video prototype provided the most compelling way to combine these ideas, and wrap them in a

narrative. The goal of this prototype was to quickly get a sense of what a bimanual productivity and fidget tool might look like in context. By forcing these ideas into a narrative, the interactions could be better considered and refined. This would also lead to new findings and ideas from these situated interactions.

Taking the ideas from the second brainstorm, all somewhat united by the personas and narrative proposed, I quickly combined them to get a sense of these interactions in context. To push the prototype as far as possible, I used very little discretion in choosing which ideas to include. I combined some like ideas, then included as many as possible to see what situations might arise. In the end, this prototype took the form of a 5-minute video of the different interactions that can be performed with the 'BiManuBall' by three creatives, collaborating on an album.

Personas

The basic user profile for this story is a creative professional, who uses a computer at some stage in their process. From this, I created three concrete user personas:

1. *Maggy Music* is an audio engineer, who needs to create every day. She works as a music producer, and generally makes one concept album with an artist every year, as well as a handful of smaller projects and collaborations. When she's stuck she'll often go for a walk to clear her head.

2. *Arty Artist* is a digital artist, and graphic designer, who prefers to do commission illustrations. He used to do landscapes, but is moving towards portraits, and has also begun experimenting with painting. He finds that drawing first thing in the morning, before even getting out of bed, helps with inspiration and motivation.

3. *Dez Designer* is a maker and designer who enjoys seeing things come out of nothing. She makes music for herself, but also experiments with AI art, and is involved as organizer or designer on several engineering projects at labs and maker spaces. She often listens to music while working to get into a creative, productive mood.

The details of these three personas were taken directly from my interviews, which helped form rich characters with a depth that could be mined for inspiration when any new interaction, or scenario arose. Additionally, this depth and realism provide a level of support and verification for the findings from this prototype. (In order to respect the privacy of the participants, any identifying details were removed. Additionally, while the specifics of any one persona are true, each combines details from different interviewees.) These three personas were taken almost directly from the second collaborative video session.

Scenarios & Storyboard

The use scenario was the narrative used for the second brainstorm session, and involves the creation of a conceptual music album. Dez Designer conceives of and oversees the entire project, and recruits Maggy Music and Arty Artist to help with music and visuals respectively. This informed the design scenario which introduces the 'BiManuBall' as a tool to support creativity

and collaboration. Two important sets of features enable this: collecting sources for inspiration, and sharing work.

The storyboard follows the three personas as they work on this project. Dez is inspired by an image he finds to start this music project. He uses the BiManuBall like a sponge to collect this source, and save it to a new workspace. Dez and Maggy already have a working relationship, so it is easy for Dez to connect with her. He shares his workspace with her by giving her his BiManuBall, and she joins this workspace. Arty is a friend of Dez's who agrees to help, so they collaborate asynchronously. Dez and Arty tap BiManuBalls at a cafe, and Arty joins the workspace. Maggy also uses the BiManuBall as a dial and switch to control her music production environment. Arty uses his BiManuBall to navigate colors and tools as he creates graphics for the project. Finally, Dez is managing several projects, so he can use the BiManuBall as a workspace-switcher, to change between workspaces and projects – focusing now on audio, now on visual, now on administrative tasks, etc. For a complete storyboard, please see: A.2.

Reflection

The main finding of this exercise was to show that this tool needed to be severely limited in features. In a word, this prototype could have been described as magic – a little ball that can do anything. While the many interactions from the brainstorms could clearly fit into a single tool, to explore these interactions in a rigorous way, the scope of the next prototype needed to be limited. From that specificity would arise more thoughtful interactions, and new ones implied by more specific use. This led to a reflection on which interactions were most interesting, or promising in technological potential and feasibility, as well as what connected best to the stories and themes of creativity.

Collecting and browsing sources was clearly an important part of the creative process, and especially interesting as it is barely touched on in the literature, and by existing CSTs. This is also an interesting interaction as there are many forms this could take. Also, the interactions and form of an embodied bimanual productivity and fidget tool could be explored in more depth. In the next phase of design I took the opportunity to focus on these simpler points, and probe these specific interactions.

4.4 Technology Probes

Building on the experiments in form, the brainstorming, and the video prototype, technology probes offered an exciting way to test and explore these ideas with real users, in situated interactions. Technology probes offer a way to inspect specific interactions from the video prototype, revisit ideas of form, and reconnect with the themes from the first study, through working with users in real-world interactions. Technology probes are based on "cultural probes" [44], which are described as a "brainstorming through time." The idea of a technology probe is to distribute a "seeding" technology to users to elicit novel ideas, problems and even solutions. These are especially useful in probing environments not generally suitable to traditional HCI methods, such as creativity [57].

A technology probe has three main goals: to capture data about use and users in the real world from a social science perspective, field test technology from an engineering point of view, and inspire new design ideas to support users' needs and desires. Hutchinson et al. define five

design guidelines for successful probes. Limit the *functionality* to one main feature, with maybe two or three others accessible. Keep the artifact *flexible*, by limiting the functionality but leaving its use open ended. Don't be overly concerned by *usability*, the main idea is to provoke the users so a perfect interaction isn't necessary. *Logging* is crucial to collect data that can help with later design stages, and finally, probes are best used in early *design phases* to elicit ideas.

I created three technology probes to explore in greater depth the themes from the interviews, and the implications of designing for the creative process. These interventions aimed to better understand the users perspective of introducing technology into their processes, and inspire new design directions. From there, they inspired new design insights, from both researcher and participants as co-investigators, and to a lesser extent explored the implications of the technology, and the limitations, of designing for creativity in these different environments.

Design Dimensions & Space

These probes began where the brainstorming and prototype left off, so to get a fuller picture of what this meant, I mapped out a design space, graphing all the ideas and interactions so far. The findings from the video prototype, plus the literature and themes guided the creation of four design dimensions: 1) Fidgetability - from high/playful to low/fixed, 2) Creativity - from ideation/divergence to production/convergence, 3) Embodiment - from high/physical to low/abstract, and 4) Subconscious - from open/slow to focused/fast.

From this space, I identified three areas of interest to probe. Three probes was a natural amount, based on the time constraints, and to avoid either a single usability test or a one-to-one comparison. Please see A.1, for the graph and areas of the probes.

Probe 1 - Dream Easel

The Dream Easel is a paper easel that can be fastened above your bed's headboard, and folds down to allow you to write or draw on a horizontal surface while lying in bed (see: **??**). The goal is to provide a space to record ideas while the user is awake at night, and a very easy way to record dreams and other thoughts that might occur while falling asleep, or right after waking up.

The main frame of the Easel is made out of cardboard with a drawstring to raise and lower it. It comes with an attached pen, and is designed for A3 size paper. The hooks are made of laser-cut wood, as is the large cross-like frame used to suspend the easel over the bed, behind the headboard. This paper and pen prototype takes a simplified approach to explore some ideas generated in the early brainstorms of projecting onto the ceiling above a bed.

This probe is focused on the subconscious design dimension, and also targets the "Mindfuck Mindset" theme. It is also important in exploring designing for the divergent and ideation phases of the creative process, but rather ignores the fidgetability dimension.

Probe 2 - FidgiPen

The FidgiPen is a digital stylus that eschews the standard sleek design of most digital styluses, and rather incorporates some elements that are designed to be played, and fidgeted with (see: **??**). This probe is in some ways the opposite of the Dream Easel – it primarily focuses on the production and convergent phase of creativity, as well as fidgeting. It also probes the ideas of embodied creativity with its tactile nature.

The pen has three main features: the tip can be twisted back and forth to change the stroke width, a dial on the pen body can be pushed and pulled to undo and redo, and a button on the end can randomize the color of the most recent thing drawn. From a technology side, the pen is designed to work with Inkscape, the open-source vector graphics program[3]. It uses an Arduino, rebooted as a USB keyboard, to send keyboard commands to use existing and customized keyboard shortcuts.

While I began with a basic idea, the design of the pen evolved and took shape while I was fabricating and assembling it in the lab. Initially, it was simply the stroke controller, which offered an interesting way of exploring a tactile fidget, that also introduced a powerful new bimanual controller. Through collaborating with other designers in the lab, and having visitors experiment with it, the pen's shape and functionalities evolved.

Undo was a natural next step, as its one of the most common commands in any design software. I was also interested in adding a button to the end of the pen to mimic the fidgeting properties of mechanical pens. These two intersected nicely in the form of an undo button where an eraser would be on a pencil.

Adding color control was the next addition. This was always a feature I was interested in including, as color provides a fun way to fidget and inspire creativity, and is also one of the more painful interactions in existing software [61]. Ultimately this type of control depends on the software, but Inkscape fortunately allows a lot of shortcuts for exploring colors. With the color I introduced the dial control, which was taken from a music control interface, and selected for its pleasant tactile feel. A randomize-color command was mapped to this dial, so a flick would randomize the color. However, adding redo became almost necessary with both undo and the color randomizer, and those two commands matched much better to the dial's control options. In the pen's final incarnation, the button controlled the color, and the dial, undo and redo. This had the added benefit of making the dial into an undo/redo fidget device – it could be flicked back and forth mindlessly, undoing and redoing only the last action, without causing any other changes to the work.

Probe 3 - AirSampler

The final probe took the longest to take on a concrete form. It began clearly enough as the source-saving sponge from the video prototype. However, exploring this idea, it became clear that the interesting interaction is really the exploring of saved sources, not the saving. It is easy enough to save images, screenshots or files, yet it is less clear how to explore and utilize this archive later. I also was drawn to using audio as the medium, as the first two probes focused on more visual creativity. The final requirement was to incorporate movement, to continue to explore the embodied nature of creativity, and fidget devices.

With these abstract goals I began to experiment using movement to explore an archive of sound samples. I began by testing a several sensors: to detected if there is movement or not, to track particle movement in the air, or to detect color. Detecting movement or not was too limited in dimension. Color was interesting because objects with different materials could be tracked, which could have different effects. However, I leaned away from this as it required a more elaborate set of controls, and also some work was already done in this space []. The particle sensor also worked very well because it could approximate a calculation of how much movement

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[3]https://inkscape.org

was occurring. This was the final direction, as this measure of movement created a nice mapping where less movement played a new sample similar to the previous one, while more movement selected a very different sample.

The final probe was a sensor on a stand which tracked movement beneath it (see: **??**), then used a Processing[4] sketch to select and play a new sound from a folder of 36 samples, which were sorted according to similar sounds. At this point I worked directly with the music producer who would use it, so I used a set of drum samples from his collection. Based on the movement the sensor picked up, it calculated the variance across the last 2 seconds, then decided whether to choose the same sample, a slightly different one, or a very different one. The next sample could be played by a small window with a play button on the computer. The name of the sample was displayed below that window in Processing, to allow the user to identify that sample in their music production environment.

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[4]https://processing.org

Study 2 - Creativity Techno-Fidgets

In order to evaluate these three probes, I conducted an empirical study, inspired by the goals and theory that underpin the technology probes. As mentioned in the previous chapter, technology probes are based on the idea of cultural probes [44]. Using probes has a unique benefit of collecting data and analyzing interactions through time – Gaver and Dunne explain their probes as a "brainstorming through time" – and emphasizing the development of ideas through time, which echoes the creative processes. This longer-term evaluation, in contrast to traditional usability lab tests, is a crucial part of evaluating creativity support tools, as many experts have written [42, 41, 94, 93]. Gaver and Dunne also recommend probes as a way of exploring ideas and problems that remain too undefined for more traditional approaches, which echoes the general consensus on creativity research, where even the definition of creativity has yet to be agreed upon. Technology probes then provide a powerful evaluation tool that is both open-ended, flexible and long-term oriented.

5.1 Study Design

The goals of a technology probe are three-fold: to capture empirical data about users perspectives, technical data about the technology behind the probes, and design insights from both the designer and the users to spark new ideas [57]. This informs the analysis and data collection at three corresponding levels: interviews about the probe, logs or artifacts of technology use, and an open session to elicit ideas.

The three probes I created were given to three different creative professionals for multi-day testing with participants. This was followed up with an interview when the probe was collected, which included a discussion of the probe, the artifacts created, and an open-ended, brainstorm-style discussion. The participants were recruited from communities of creatives I am connected to in Paris, France.

Participants

Three different creatives participated in the study. The Dream Easel was given to a writer, the FidgiPen to a graphic designer and illustrator, and the AirSampler to a music producer. They ranged in age from 24 to 28, and were all located in Paris, France.

Apparatus

The study used three probes: the Dream Easel – an easel that hangs above a bed to record thoughts or dreams while lying down, the FidgiPen – a digital stylus augmented with several control buttons, and the AirSampler – a device that tracks movement to explore an archive of sounds. For a more in-depth explanation of each, please see the Design chapter.

This study of technology probes involved some co-creation with the users, so in some cases the probes were altered or augmented over the course of their use.

Procedure

Each probe was delivered to the participants along with a short tutorial on the basic use. The participants were given several days with the probes, depending on their schedules: two days with the AirSampler, three days with the FidgiPen, and five with the Dream Easel. Given the limited fidelity of the probes, I remained in contact with them over the course of their use. This allowed a certain amount collaborative design and ideation during the process. After the participant was finished, I collected the probes and conducted the interview for approximately one hour.

Data Collection & Analysis

I took handwritten notes, and recorded audio of the interviews. I also collected artifacts from the creative processes of the different users when possible. The artifacts were used as discussion points in the interview.

The interviews were analyzed with a focus towards collecting new stories and experiences, and finding new design directions and insights for a next level of prototypes. This qualitative data was analyzed with three lenses based on the goals of technology probes: extracting user experiences and stories, dissecting the technology, and looking at what new insights, ideas or designs were generated. The main focus was on the former and the latter to develop the next directions for this work, and because the technology was generally a means and not the focus, however certain aspects or limitations of the technology did produce insights.

5.2 Results & Discussion

I recorded three interviews, one from each participant. I also collected two illustrations from the FidgiPen, and one song from the AirSampler, but the artifacts from the Dream Easel felt too personal for the participant to share. Each interview generated new stories and experiences, reflections on the technology, and several ideas for designs or directions. From the Dream Easel I collected 12 novel experiences or insights, eight from the FidgiPen, and 14 from the AirSampler. These findings, and related discussion, are divided into three sections, for each of the three probes.

Dream Easel

The main findings of the dream easel relate to the experiences with this design, and point to promising future directions. The primary findings revolved around the routines of using the easel, and there were two main points: the way the participant used it created an interesting collage as the days passed, and its physical presence helped to force encounters.

The participant explained they had only used one page over the several days of use because they didn't want to waste paper, "I felt bad personally, of using so much paper." While the easel was designed for pages to rip off every day, using one page created an interesting collage of thoughts and ideas over the course of the Easel's use. This additive nature helped to establish a routine even in the short time the easel was tested. Using one sheet also forced the person to create some divisions, and while these weren't explicit, "not a grid", gradually different areas of the page took on different meanings – for example a to-do list. Also, not facing a blank sheet because of the built up content was appreciated, "it was also nice actually, after the first night

to see that it's not blank." Seeing these old notes helped when going to sleep, and made it easy to add a little more. Building on this, the old notes also provided a good distraction for writers block that is much more productive, and less dangerous, than turning to your phone. One specific routine that developed was a "key realization of the day," a short lesson learned, meaningful thought, or experience from the day. Seeing the past realizations was helpful in maintaining this routine, either encouraging to write again, or inspiring the next realization. The participant said they had tried this type of routine in a journal before, but it didn't feel as "special," because the notes were "hidden in the pages" and not building up next to one another. This "special" physical-ness of the easel is another key part of establishing these creative routines, with its mere presence, the easel was a good prompt. This was both a help in the evening or night to jot down notes, but also functioned during the day. The participant explained how they would sometimes quite literally bump into this large easel hanging over their bed. And, while they didn't necessarily want to lie down during the day to use it, seeing past notes was helpful for inspiration or as a reminder to be creative. The participant even said they had similar creativity-reminding items around their apartment, but they were not as successful as the large easel hanging over their bed. Both sides of this experience of routine also augment the stories of creative mindset and process collected in the first study.

Some other interesting stories included the value of the larger format paper, privacy concerns, and collaboration. This participant is a writer who generally uses notebooks, but they found the larger format (A3 paper) to be an exciting jolt to their work. They even took some of the extra sheets off the easel and placed them around their apartment to have a more continuous interaction with ideas in their living space. A related aspect was the question of privacy and the personal nature of your dreams and reflections at night. In this way the paper size was a problem. The paper was designed to be easily removed to be taken anywhere, but as the participant noted, unfolding an A3 page is not always convenient, especially when it is covered in personal musings and dreams. This also came into play when visitors came to their apartment, even though the easel was in their bedroom, they would hide the paper just in case. For this reason the participant was glad they lived alone, although we wondered about the implications and possibilities of sharing with a significant other, or friends. Were this prototype to take a on a higher-tech form, perhaps there could be some idea of sharing ideas, where some dreams and ideas are private, but others can be shared to friends' or family's Dream Easels (for example, the daily realizations).

Finally there were some technology problems and considerations that have implications for future similar projects. Writing above your head, in the dark, is not an exact science, the writing is awkward, ugly, and even unintelligible sometimes. We discussed using audio to record ideas instead of a visual medium, however, the participant felt that some ideas were hard to voice, but easier to express visually or written. This would also make corrections much harder – you can't cross out audio – and would introduce a new challenge to designing a fluid way to "bump" into the audio easel. Their solution to this was writing problem was to use Post-Its, which they could easily write on in bed, then stick onto the easel as a place to aggregate notes.

All these stories, and ideas, suggest that this easel was quite a successful early prototype in designing to explicitly support the creative process through activating a creative mindset. The Dream Easel was very low fidelity, however in this study there are some very clear successes and implications for further designs aimed at engaging with the subconscious and early, divergent creative processes.

Fidgi-Pen

In contrast to the Dream Easel, the goals of the FidgiPen were much more techno-focused because it targeted the production phases of the creative process. To this end the findings primarily revolved around the experience of using the pen, especially in contrast to the participant's other pens and drawing tools. It is important to note that the undo/redo and color changing buttons did not work for the whole time and so those functions are generally ignored.

One key quote is that the stroke changing felt magical: "I do feel this kind of magic that the stroke can change continuous... I've never experienced that before." This is inspiring because it shows how a simple change from software to hardware controls can achieve a profound effect, and while this may be designed as somewhat of a manufactured obstacle, in practice it feels inspiring.

The bulk of the findings from this probe are related to the tactile nature and feel of it. Again the stroke changing was important – it nicely echoes the way pencils, pens and markers can be used at different angles to modify the line width, but with the cool change of having "no limit, you can draw from really thin to really thick." The pen's smaller size was also a surprising asset, which allowed it to be held either like a pen or "like chalk." Holding it like chalk created an interesting tactile effect where the pen had a sensation of squeezing because the button then sat in the middle of the palm (this was only possible once the color function no longer worked). The softer, finger-like quality of the tip was another important tactile aspect. The pen tip was taken from a stylus with a soft rubber texture, which contrasts nicely with the fine, hard tip of the Wacom pen the participant normally used. This rubber tip provided some drag which was reminiscent of pen on paper, and felt much more natural than the Wacom. (This drag did create some problems with the software creating continuous smooth lines.) While the FidgiPen couldn't mimic a mouse like the Wacom, this broad tip had a nicer, more specialized drawing feel. They also appreciated the dedicated nature of this tool, which they likened to the specific pens or pencils they use in paper illustration to achieve different effects. This led to the participant imagining the potential of a set of these FidgiPens, "imagine having a set of styluses, different styluses represent different kinds of tools." We discussed two logical versions of this, either a set of different pens, or having exchangeable tips, for example a stroke one, a color one, a fine one, a soft one, etc.

There were also some clear limitations and problems with the technology. First and foremost the buttons were unreliable. Also, the stroke changing mapped oddly to the speed at which the tip was rotated – a slower speed allowed a larger range, while rotating faster limited the range. This was due to the mechanical to software mapping, and the participant clearly noticed this, and was then curious about the intent or meaning, and then unsure how they felt about this variability. Finally, to use the pen on a capacitive touch screen meant holding it by the metal tip, which was sometimes awkward, and interruptions meant line segments might be broken into multiple lines. All these combined to mean working with the pen was unnaturally slow for their illustration process.

Despite some technical hiccups, the FidgiPen was a very productive and inspiring probe for its main goals of exploring how more natural and tactile sensations could be re-introduced to a digital stylus. The main findings about the feel of the pen are very promising for follow-up designs that would continue to incorporate tactile and fidgety elements into bimanual controllers. This is perhaps not surprising given the role of manufactured obstacles in creativity, but this probe provides and interesting case study in how this can be a design goal.

AirSampler

The AirSampler was slightly different than either of the other two probes, and involved much more co-creation over the course its use between researcher and participant. As problems and ideas arose, the probe was modified as much as possible to accommodate these new insights, which then led to new problems and ideas, and so on. The results are presented and discussed chronologically to attempt to capture this evolving process.

The initial findings relate to how the probe fits into the existing workflow of producing music, and the problems with introducing a new layer to that. For example, the software component of the probe meant there was a new window that the participant had to have open and be able to click to play the samples, which became a problem because it required the free hand (the one not using the AirSampler), and required switching between applications. Surprisingly, after playing a sample, it was not such a big issue to select that sound from their files, and move it into their Digital Audio Workstation (DAW). The extra application window became an even bigger problem when the participant was working with video. Part of their process involved playing a video to inspire a mood and feel for a new song – which was also an interesting new story of the creative process. However, this video took up one screen, the DAW used their second monitor, and the AirSampler's window was then awkward to use. This led to an important idea and change, to be able to use the AirSampler better without looking, so we removed the stand, and it became a hand-held shaker device. This was a very successful update that allowed more mindless exploring of the audio samples, even if the software still had to be used to play them. It was also nice that the interaction echoes shaker instruments.

One finding that adds to the stories of creativity and mindset is that the "biggest creativity killer" is bumping into software. This arose a lot with switching between applications to use the AirSampler, and especially when the audio wouldn't work correctly. The audio for the AirSampler had some troubles playing through the correct channels for the DAW which was very frustrating and "dispiriting."

As they got more experience with the AirSampler there were some other usability considerations. The speed with which samples change was a problem, and sometimes the best sample was relative – "would be nice to have like four [previous samples]"– so it was a problem that the AirSampler had no notion of history or back controls. Also, there were two bugs with playback that became more noticeable with time. There was a problem with sample IDs, where the ID from the AirSampler software wouldn't the same ID in the archive. The playback of a sample could also be delayed sometimes, which was annoying if you tried to play the sample on a specific beat. However, both these bugs were not such problems in the end, this aspect of being "not fully in control... actually made it fun," the extra randomness only fueled creativity, whether it was a surprising sample, or unexpected timing for a sample to play. This more extreme randomness was also likely saved by the fact that all the samples were pre-selected – they were taken from the favorite folders of the participant – so they generally liked all of them.

Speaking to the changed form factor of holding the AirSampler in their hand rather than on their desk, this tangibility was much more "fun." This also connected to the ideas of fidgeting and self-regulation, "it's fun to have something tangible in your hand like this... I like the fact that I can, you know, sit there and play with something in my hand." Also, it's small shape lent itself well to this action, "maybe it's because of the shape... I enjoyed this shaking of it." However, this was still limited by the software play button, "it would be good if you could also

play the sound from your hand there." Moving the play button to the shaker itself would greatly improve the flow and feel of using the AirSampler. This integrated controller could become a cool instrument of procrastination and creation, "while you're listening to your song, you can just like lean back with this thing in your hand."

The shaker also brought comparisons to drum machines the participant uses in their music production. One interesting story was that the participant rarely uses all 16 pads on the machine, but prefers to use a few to experiment with how some different samples sound in the song their working on. They use the pad to experiment when they are looking for some sound, for example trying high hat cymbals, "I only have hats because ... I'm working on a song... and I'm like, okay, I need the hat. And then I go in there, I have the group of hats." They are attracted to the idea of a smaller device then, "it's still a massive thing and would be fun to just have a small device." This example of exploring high hats raised a question about exploring an entire archive versus only a preset selection. The AirSampler uses a whole archive, which was anticipated to be a slight speed bump, maybe even counterproductive. However, they actually appreciated that it made it easier to have serendipitous encounters, "It's nice to have that suddenly, I think I need a hand [clap], but then a snare comes on and I'm like... this too sounds nice." One final experience was that they end up using their keyboard more than the drum machine anyways because it is easier to connect to, the drum machine involves some setup that "interrupts your workflow." This also led to a story about switching from the keyboard to the drum machine to overcome creative block by using a new interface – "I'm so used to playing the keyboard and I am like stuck... So I take this thing [drum pad] and just the fact that it's a different sensation [helps]."

Finally, this probe may have ended up being the most promising in terms of future directions. It was very successful in starting a dialogue about engaging with an archive through movement, and specifically using a bimanual and fidget tool. It also uncovered several new stories of the creative process and how creativity is enabled or inhibited. This probe is also still evolving, the participant and I are still collaborating and working on a new version. With some small changes to address some of the new findings, this producer hopes to integrate this technology into their creative process.

Conclusion and perspectives

This project pulled two main threads together: designing for creativity and especially serendipity, and using bimanual tools as a way to engage with the embodied nature of cognition and creativity.

This began with a comprehensive literature review to frame this project within the existing HCI research in these realms. Various research has explored bimanual tools, but these have only been proposed within the classical goals of HCI, increasing productivity and speed. Creativity is also slowly being considered in terms of embodied thought, yet this has yet to be connected with bimanual interaction. In creativity research, the main body of work on Creativity Support Tools is focused on the medium- to late-stage creative processes of aggregating ideas and production, and rarely tries to support earlier stages of inspiration and serendipity. Additionally, few of the tools that have been developed are based in new neuroscience and psychology ideas that see creativity as an embodied process. These gaps and connections in the state of the art were probed using a research through design approach that explored bimanual tools for creativity.

To fill out this base of knowledge with real user stories and experiences, I conducted a first study to interview different creative professionals, and gather stories from online communities of creatives. These interviews produced three themes and five sub-themes with implications for designing technology to support the creative process. These themes were further supported by stories collected from the online creative forums. Armed with the theory from the literature, and the stories collected from users, I entered a design phase to create artifacts to test how to design bimanual creativity tools.

From early experiments in forms, to collaborative brainstorm sessions, and eventually a video prototype, the designing concluded with the creation of three prototypes, or technology probes. These three probes crystallized three main areas of a design space that was generated over several ideation phases based on the user stories and theory. The first was the Dream Easel, an easel that hangs above a bed to encourage recording thoughts or dreams while lying in bed, to explore how designs can be aimed at the subconscious. The second was the FidgiPen, an augmented digital stylus which probed how to design a tool for fidgeting and productivity, and introducing embodied interactions. The last was the AirSampler, which used movement to explore an archive of sounds, to examine the interactions of exploring an archive, and designing for embodied creativity and fidgeting.

This project concluded with three explorations, where each probe was left with a different creator for several days. Rather than classical usability tests, this second study was oriented towards gathering new stories and experiences, generating new design insights or directions, and exploring the technology possibilities. The new stories discovered, and novel directions implied by these probes suggest promising avenues for future work, and new perspectives on designing to support creativity. They spoke especially to the value of engaging with the body and the potential of fidgeting. There was also some indication of ways in which designs can be left open and simple to encourage wider ranges of use and experimentation, and ultimately serendipitous encounters.

Acknowledgments

I would like to thank XXX...

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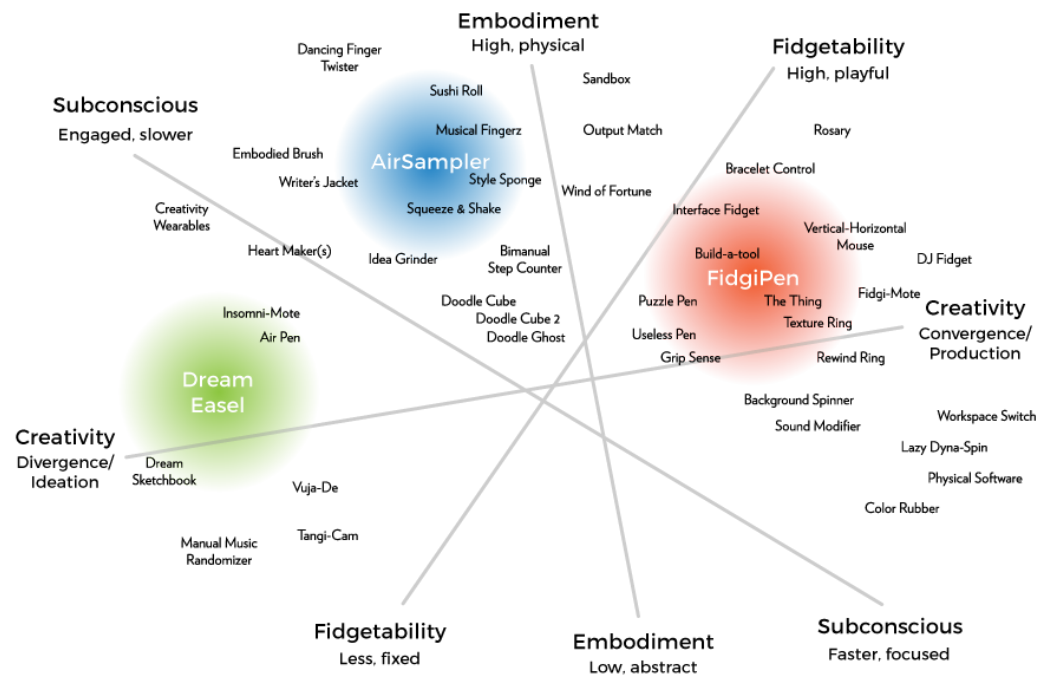
Appendix

A.1 Images

Experiments in Form

Some of the experimental shapes, annotated for successful and unsuccessful fidget qualities.

Design Space

Embodiment
High, physical

Dancing Finger Twister

Sandbox

Fidgetability
High, playful

Sushi Roll

Subconscious
Engaged, slower

Musical Fingerz

Output Match

Rosary

Embodied Brush

AirSampler

Bracelet Control

Writer's Jacket

Style Sponge

Wind of Fortune

Interface Fidget

Creativity Wearables

Squeeze & Shake

Vertical-Horizontal Mouse

Build-a-tool

Heart Maker(s)

Idea Grinder

Bimanual Step Counter

FidgiPen

Puzzle Pen

The Thing

DJ Fidget

Fidgi-Mote

Doodle Cube

Texture Ring

Creativity
Convergence/ Production

Doodle Cube 2

Useless Pen

Insomni-Mote

Doodle Ghost

Grip Sense

Rewind Ring

Air Pen

Dream Easel

Background Spinner

Workspace Switch

Sound Modifier

Creativity
Divergence/ Ideation

Dream Sketchbook

Lazy Dyna-Spin

Vuja-De

Physical Software

Manual Music Randomizer

Tangi-Cam

Color Rubber

Fidgetability
Less, fixed

Embodiment
Low, abstract

Subconscious
Faster, focused

A.2   Video Prototype Storyboard

- Dez and Maggy are friends who often collaborate and work on projects together.

  [Split screen shot of both characters]

- Dez is procrastinating Friday afternoon by browsing Reddit – scrolling through her curated homepage of some music and art – when she sees a space illustration which gives her an idea for a music project.

  [Panning shot from Dez onto her screen back to her face, to idea – save post? write down idea?]

- Dez and Maggy chat that evening and Maggy agrees to write a song.

  [Scroll message history of chat]

- Dez shares her concept for the album with Maggy – "a journey to the end of the universe".

  [Send a 'workspace': a collection of inspirations, sources, ideas and notes]

- On Saturday morning, Maggy starts working on a new song for this project. She begins with an old song she was working on yesterday.

  [Pan from desk with coffee to screen, open/duplicate recent project]

- Maggy clears some of the details from the track, to end up with a couple notes making up a simple chord progression.

  [Scroll timeline by twisting the BiManuBall, then delete clutter from timeline]

- Then Maggy switches to her archive of saved sounds, samples, and old work.

  [Open a sound archive browser]

- Maggy browses for something that sounds or feels kind of "space-y".

  [Scroll archive by twisting the BiManuBall]

- Maggy saves a couple spacey sounds she finds..

  [Tap the BiManuBall save]

- Maggy adds the saved sounds to the workspace.

  [Squeeze BiManuBall to deposit saved sounds into project]

- Maggy plays with the song for the afternoon.

  [Using BiManuBall as dials/sliders inside DAW]

- Maggy gets stuck

  [Starts to play with BiManuBall]

- Maggy decides to take a walk to clear her head.

  [Leaves her work, takes the BiManuBall out on a walk]

- Maggy finds some inspiration on the walk.

  [Saves images/sounds/ideas into the BiManuBall]

- Maggy takes a look at the project and decides to send incomplete ideas to Dez for some feedback.

  [Open project, share workspace back with Dez]

- Maggy forgets about the project for the rest of the weekend.

  [Close laptop and leave]

- Dez talks to Arty about creating visuals for the album on Saturday morning.

  [Meetup for coffee or at a park]

- Arty agrees to help, so Dez shares the project.

  [Bump BiManuBalls to share workspace]

- Arty spends some time that afternoon looking through old work.

  [Scroll through work with BiManuBall]

- Arty saves a couple old works and ideas.

  [Tap BiManuBall to save]

- Arty begins to sketch a composition. [Create a new project/workspace]

- Arty adds ideas from his old work.

  [Squeeze BiManuBall to deposit sources]

- Arty switches between his new composition and old work.

  [BiManuBall as workspace switcher]

- Sunday morning, Arty quickly sketches some paper and pen ideas before even leaving bed.

  [Sketching in bed]

- After breakfast, Arty transfers his sketches to his digital workspace.

  [Walk over to desk with coffee, take snapshots with BiManuBall]

- Arty works for awhile.

  [Using BiManuBall as colorpicker, stroke selection, etc. . .]