Designing for the Physical Margins of Digital Workspaces: Fidget Widgets in Support of Productivity and Creativity

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ABSTRACT
We present our ongoing work to develop the concept of physical "margin" spaces around software and a new type of human computer interaction. Our novel "Fidget Widgets" seek to engage users' interrelated bodily motions, affective states, and cognitive functions to selectively enhance creativity, focus, calm, etc. Building playful interactions embodying "mindless" activities like doodling, fidgeting, and fiddling, we are working to demonstrate the value of incidental tangible interactions in the physical spaces surrounding digital workspaces. We intend these secondary interactions to have no intrinsic goals; rather these interactions extrinsically enhance a user's state toward the completion of their primary tasks.

Author Keywords
Tangible; play; margin; productivity; creativity; affective; cognition; doodle; fiddle; fidget; Sifteo.

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

General Terms
Human Factors; Design.

INTRODUCTION
Work today is as much cognitive exercise as it is physical exertion. We think, analyze, and create in front of computing interfaces in our offices, classrooms, labs, and studios. We observe from people at work that brainstorming engages forms of embodied cognition. We fidget with paper clips, tap pens, squeeze stress balls, doodle in notes, scoot mice about, and generally play with any item at hand while we contemplate problems, draw connections, and await inspiration. Though we work by interacting with software, our thinking extends into a physical "margin" space around our software through doodling, fidgeting, and fiddling [18].

Doodling has been shown to increase attention in monotonous tasks and to improve recall [2]. Fidgeting is theorized to modulate focus [8,11,24]. We see opportunity to design for tangible interactions that harness these and other effects in a novel manner removed from traditional HCI work. That is, our goal is outside the interactions. The effect is to be solely within the user, created through play in the physical margin space around a digital workspace, and enabling of productive, creative workflows.

Research draws a clear link between affective state and effectiveness in cognition (see Existing Work section). Informal observations of those at work playing with objects suggest the potential for a new interaction experience.

We envision providing digital workers a "sampler box" of interaction experiences from which they can selectively modulate their own state to yield appreciable gains in focus, creativity, calm, etc. To that end we introduce our concept of "Fidget Widgets" as playful, secondary interactions able to engage the interrelation of bodily movement, affective state, and cognition to support primary serious tasks. We intend these interactions to be both more intentional and more capable in having effect than their analog inspirations.

Figure 1: Toys in our lab for thinking and inspiration.

TERMINOLOGY
In this paper we repeatedly refer to "doodling", "fiddling", and "fidgeting." These terms are worthy of clarification.

Doodling is absentminded scribbling — often in a margin.

Fiddling is playing with an object usually through absentminded manipulation with the hand. Objects may be paperclips, pens, magnets, computer mice, stress balls, etc.

Fidgeting is purely a bodily action, usually enacted absentmindedly and repeatedly. Fidgeting includes finger drumming, leg bouncing, tapping out rhythms, etc.

PHYSICAL MARGINS OF DIGITAL WORKSPACES

In the analog world, we have margins. Whether it is the ruled edges of notebook paper or the shoulders of a highway, physical spaces include margins. We utilize margins in unexpected and often creative ways to support our work tasks. Software systems tend to be purpose built without margin. Word processing documents do not generally support doodles. If there is any "scratch space" in a spreadsheet it is a region of cells appropriated by the user.

We observe that users of software tools make use of a workspace larger than the digital one contained in a computing device. Papers and books and other items extend the workspace. Further, digital workers' thinking processes extend into the physical space and tangible objects immediately around a digital workspace. That is, like doodles at the edge of a notebook, digital workers actively think in the physical margin surrounding their software. As we will establish in the Existing Work section, components of thought are interrelated with bodily motion and sensation — in particular that of the hand. We submit that doodling, fiddling, and fidgeting behaviors are an opportunity to build tangible interactions that support and extend these naturally self-modulating behaviors. Such tangible interactions can digitally enhance the physical margin surrounding software.

FIDGET WIDGETS

To explore and test our ideas we are creating small "Fidget Widgets." The following characterize the concept:

- Tangential. One "mindlessly" engages a Fidget Widget while mulling an idea or paused in work.
- Playful. The goal is the experience of the interaction not achieving a goal with the interaction itself. [See section Defining a Playful Technology.]
- Digital. To allow for supple experiences [14], flexibility, and effect in users greater than possible in analog objects, Fidget Widgets are programmable. Interactions are reactive but not necessarily predictably so.
- Tangible. Engaging the bodily movement inherent in our inspirations of fiddling, fidgeting, and doodling, Fidget Widgets embody physicality beyond screen abstractions.

EXISTING WORK

Doodling & Other Relevant Interaction Projects

Doodle Space paired camera phones and public displays for collaborative expression [39]. Doodles have been utilized as alternative password mechanisms [12,36]. Levin and Yarin developed "keychain" computers to implement small gesture-based systems inspired by doodling [22]. Common to each of these projects is a simple adoption of a doodling mechanic without deeper motivation for its employment. That is, these researchers and practitioners recognized doodling as an interaction but made no explicit declaration as to its motivation of use or hypothetical benefits.

Inspired by Chinese meditation balls, Philips created wood LED-studded *Mind Spheres* as "a useful aid for de-stressing and regaining a state of mindfulness at home or work" [29]. This project certainly engages bodily movement and sensation towards influencing affective and cognitive state. In this sense, it exists in the same domain as our work. However, in our work, we are interested in tangential, "mindless" interactions as much as those that absorb user attention. The *Relax!* pen by Alonso senses telltale motions associated with stress and provides a calming tactile response [1]. This project is similar to our approach, but our work spans a range of user states and is intended to be more generally applicable in work contexts.

Impact of Affective States on Cognition

Research demonstrates numerous links between affective states, performance, and cognition. Mildly positive affect promotes creativity and cognitive flexibility [3,17]. Anxiety and signs of impeded progress toward goals have been shown to increase focus and attention [21,28]. Sadness and anxiousness have been shown to prime uncertainty reduction during decision-making [34]. It is these effects we are designing for with our Fidget Widget concept so as to provide users choices in self-modulating their own state.

Embodiment and Affective State

A phenomenological approach to human computer interaction has shifted thinking to consider not only the abstractions and mental models of interactions but the entire physical and emotional experience of interacting with computing interfaces [5,10].

Research shows a strong link between our bodies and our feelings; the former strongly influences the latter. Carney, et al have shown that holding one's limbs away from the body even for a short time ("power poses") increases confidence [6]. Contorting one's face to activate muscles used in facial expressions is known to induce feelings correlated with those facial expressions [27]. Recent research demonstrates that superstitious practice enacted bodily and involving interactions with objects and physical spaces (e.g. knocking on wood or tossing salt over one's shoulder) impacts an individual's beliefs and expectations of the future [38]. Other work has explored design of gesture-based interfaces towards modulating affective state in human computer interaction [15,16,20,30].

We submit that interactions can be designed to induce changes in affective state complementary to one's work. Further, we believe any success to be found in such interventions requires tangible, embodied interactions rather than mouse-driven or even multi-touch interactions.

Impact of Bodily Movement (the Hand) on Cognition

New research is developing a compelling link between the act of writing (i.e. pen on paper) and cognition. The effects in the brain due to writing are far beyond that involved in typing or even touchscreens [4,23,37,40]. Neurologist Frank Wilson summarizes: "Any theory of human intelligence which ignores the interdependence of hand and brain function, the historical origins of that or the impact of that history on the developmental dynamics in modern humans, is grossly misleading and sterile" [40]. Dr. Virginia Berninger notes that handwriting requires sequential strokes whereas use of a keyboard involves only a single key press. Berninger has observed in brain scans that sequential finger movements activate large brain regions involved in language and working memory [4]. We submit that tangible interactions have potential to induce changes in cognition that are complementary to one's work.

Fidgeting, Noise, Focus and the Brain's Default Network

In "hyperactive" and ADHD children, researchers have hypothesized that fidgeting is a coping mechanism the body employs to promote natural stimulant release, enabling the mind to focus on tasks [8,11,24]. Anecdotally, encouraging fidgeting in the classroom through desk design and seating seems to improve focus in children [25,35]. From these, we extrapolate that we can design interactions to enable fidgeting tendencies that modulate focus.

Similar to mildly positive affect, moderate levels of ambient noise have been shown to increase creativity [26]. In fact, the startup Coffitivity provides tunable coffee shop ambient sounds to boost creativity [41]. That is, software-based audio has been designed to spur creativity in cognition. Consequently, we conclude that designed audio interactions consistent with the goals presented herein can also modulate cognitive state.

The brain's so-called default network seems to establish a baseline of activity, engaged in boredom, impatience, and indecision. Researchers have noted parallels between the motor activities of doodling, fidgeting, and fiddling with objects and the patterns of activity in the default network of the brain [32]. Questions remain as to whether "mindless" doodling consumes resources, detracting from tasks at hand, or whether it improves performance by aiding concentration through regulation of arousal and cognition [2]. We find it plausible that tangible interactions can engage the brain's self-modulating mechanisms able to deal with boredom, decision making, etc.

PROJECT INSPIRATION

A simple observation of a student's behavior during a class formed the genesis of the Fidget Widgets project [18]. This particular student, like many of her peers, was using software on her laptop computer to take notes during a lecture. We observed her mindlessly using the arrow keys of her laptop keyboard to rapidly bounce her screen cursor back and forth among the letters and spaces in her notes. In a fashion, this behavior was crudely reminiscent of doodling. This inspired questions such as:

- Doodling usually takes place in the margin areas of paper; how might human computer interactions with software incorporate "margins"?
- How can we facilitate and encourage play and playful interactions? How do we do so without constructing games? That is, play in software most often takes the form of games, but we wish to create interactions here that are free of a goal orientation. [See section Defining a Playful Technology for more on this topic.]
- An input modality tends to shape a user's interaction and movement. If only a keyboard or mouse is present in a workspace this seems to limit hand actions to those afforded by these devices. How can we facilitate greater manual dexterity and manipulation akin to true fiddling?
- How might we design and construct secondary, incidental interactions that are "mindless" like doodling, fidgeting, and fiddling? Can these design interventions support and complement thinking and working productively?

DEFINING A PLAYFUL TECHNOLOGY

We use *playful* specifically to distinguish our work from that of games. Philosophers, sociologists, anthropologists, and others have put forward many definitions for *play* [31]. While we could fill this paper attempting to draw a line between "gameful" and playful, for our purposes, we will loosely define a playful activity as one:

1. Free of measurable goals;
2. Undertaken for an intrinsic motivation — that is, for the enjoyment of the experience itself;
3. Usually embodying delight, levity, or silliness.

From this, we can distinguish games from playful activities in degree. Games tend to be structured and tend to be extrinsically motivated by points, achievements, and/or status. Conversely, playful activities tend to be unstructured and engaged for their own sake (e.g. building with blocks, playing dress up, paper airplanes, etc.). Playful technologies, then, are material constructions that facilitate playful interactions — often with electronics and software.

WORK TO DATE

Design and Study Challenges

Our Fidget Widgets concept has proven challenging to design and test. The behaviors from which our concepts are inspired are "mindless" and tangential, complicating traditional design processes meant for directly yielding productivity. Usability and psychologically-based testing are generally best accomplished with direct interaction, focused attention, and measurement of quantifiable primary effects. Our concept is antithetical to these approaches.

Iterative Design and a Supple Approach

Given the inherent challenges, our approach, then, is iterative in understanding our users, the effects for which we are designing, and the design of Fidget Widgets themselves. Rather than an overly structured approach to addressing many difficult complications, we are instead employing a "supple" design and study strategy [14].

To date we have used lo-fi methods to understand basic user behaviors and find the edges of our design envelope. We used a survey to get at doodling, fiddling, and fidgeting behaviors individuals employ in their work. We have built two exploratory instances of the Fidget Widget concept. With these, we have sought expert opinion and user reactions to guide further development. At present we are investigating the Experience-Sampling Method to surmount our study design challenges [33]. Our work and findings thus far are discussed in the sections that follow.

Survey of Behaviors During Computer-based Work

We created a web survey that collected 35 responses on doodling, fiddling, and fidgeting behaviors during work. While the results are surely biased by self-selection, it reveals interesting trends nonetheless. A web-based survey aligned well with our target user population.

Demographics

Survey respondents ranged from 21 to 47 years old. Gender was nearly evenly split between 19 males and 16 females.

Doodling, Fiddling, and Fidgeting Behaviors

91% of our respondents doodle, fiddle, and/or fidget while working alone; 90% of these reported doing so multiple times a day. Of the 32 respondents self-identified as engaging any of these behaviors while working, 25 reported regularly engaging two or more of the behaviors.

Attitudes about Behaviors

Only 4 respondents identified these behaviors as "wasteful"; the remaining of respondents were evenly split between "neutral" and "beneficial." One respondent added their own descriptor of "fun."

Patterns in Self-Reported Behaviors

Descriptions of doodling, fiddling, and fidgeting behaviors varied greatly. However, a commonality emerged. Whether it was describing doodling, fiddling, or fidgeting, respondents used a language of repetition. Doodles repeated a pattern. Fidgeting was a repeated motion. Descriptions of fiddling often included explanations of how objects were manipulated in the same manner again and again.

Conclusions

If these results are at all representative of the population at large, researchers may have missed important behaviors quite common and integral to modern work. Further, it appears that repetition may be a key component to the "mindlessness" of doodling, fidgeting, and fiddling.

Early Fidget Widgets

Form Factor: Sifteo Platform

Our two exploratory Fidget Widgets are applications running on first-gen Sifteo cubes [42]. Sifteo is comprised of squat blocks at 4.3 cm (1.7 in) on a side and 1.8 cm (0.7 in) deep. Each includes a color clickable screen (i.e. the entire screen is a physical button) and sensors to sense shake, tilt, rotation, flipping, and proximity to one another.

We chose to work with Sifteo, in part, because it affords interactions similar to the fiddling and playing with objects common to desk workers. Their limited computing power has helpfully restrained scope. Further, Sifteo is a readily available tangible platform that allowed quick prototyping.

Form Factor: Observations on Smartphones

In the course of our work we have received criticism from HCI practitioners questioning why we have not simply built smartphone apps. Our rebuttal is threefold:

1. The weight and size of a smartphone is too great for effective fiddling in light of the preferred objects (e.g. pens, paper clips, stress balls).
2. Smartphones carry with them a certain "baggage" of expectation in use and convention.
3. Especially given feedback received (discussed in a later section), smartphones provide far too little tactile experience to achieve our goals.

Infinite Bubble Wrap

Noting the visceral reward in popping physical bubble wrap and the common desire to pop bubbles repeatedly, in this interaction we created a never-ending supply of virtual bubble wrap. Each Sifteo cube is a single bubble. The screen shows two states: an inflated or a popped bubble (see Figure 2 and Figure 3). When a user depresses the screen, the cube transitions from inflated to popped with an audible pop. Shaking the cube triggers an inflation sound and resets the bubble. When cubes are placed together forming a "sheet" of bubble wrap, popping any one bubble begins a chain reaction popping each of the others in sequence. Note the key elements of repetition as revealed in our survey.

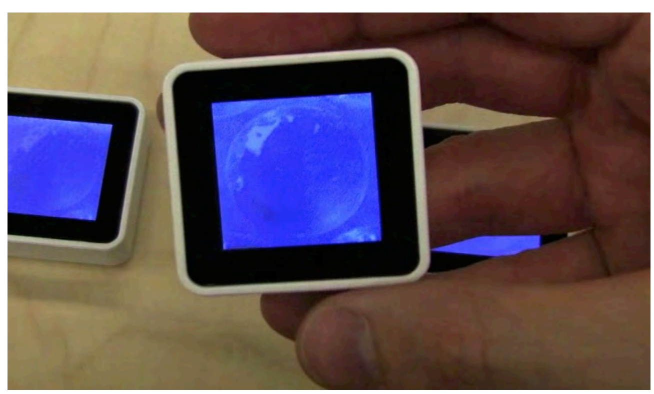

Figure 2: Infinite Bubble Wrap inflated state

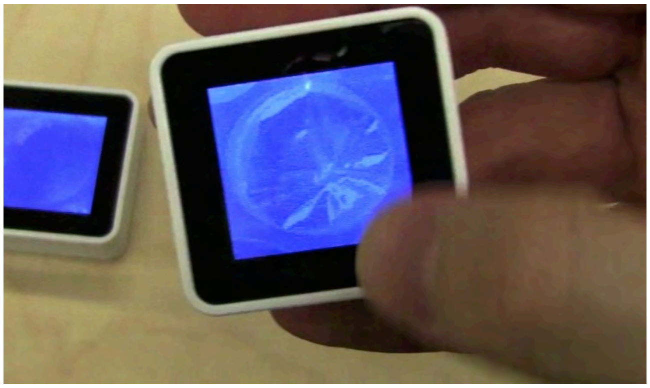

Figure 3: Infinte Bubble Wrap popped state

Rock the Cradle

Newton's Cradle is a classic physics-based toy (see Figure 4). Noting the almost hypnotic effect of Newton's Cradle, we created virtual Newtonian worlds with Sifteo cubes. Depressing a cube screen creates a new "pellet" in that cube's world. Tilting ("rocking") a cube simulates gravity in that cube's world and imparts velocity to the pellets with it (see Figure 5). A 2D physics engine manages motion and bouncing. Pellet collisions generate musical tones (overlapping collisions create chords). When cubes are brought next to one another, the bounds of each cube's world disappear allowing pellets to interact within a universe as large as the touching cubes (see Figure 6). Removing a single cube from such a universe "traps" pellets within it, limiting their motion to the bounds of that cube. The whole of the interaction is similar to the experience of playing with ball bearings or marbles and also with wind chimes. Note the rhythmic qualities as revealed in our survey.

Figure 4: Newton's Cradle
[Image courtesy of Ant Holnes via Creative Commons]

Figure 5: Pellets bouncing about their individual worlds. The leftmost cube is being rocked to impart velocity to its world.

Figure 6: Individual cube worlds combined into one universe by physical proximity. Note that any configuration of touching cubes is possible. Moving and rotating individual worlds reorients those worlds within any universe of touching worlds.

Expert Reviews

Given the challenges in design and rigorous study formulation noted previously, we elected to conduct expert reviews with the attendees of CHI 2013 to explore our design space and elicit insight and feedback. We conducted 9 reviews using our Infinite Bubble Wrap demonstration [19]. Reviewers included a doctoral student studying new video applications, an HCI practitioner at Samsung, a former Sifteo employee, an MIT Media Lab student, an engineering professor, a tangible interface researcher, and usability expert Jakob Nielsen, among others. These reviews each lasted from five minutes to nearly an hour.

Our expert reviews were comprised of two components:

1. Think-aloud sessions using the existing Infinite Bubble Wrap Fidget Widget implementation;
2. Semi-structured interviews grounded in these HCI experts' own doodling, fidgeting, and fiddling behaviors as well as their relevant backgrounds.

Overall Reactions

Each of our 9 reviewers reacted quite positively and even enthusiastically to the Fidget Widget concept — even when pressed beyond any social niceties. Of course, several reviewers rightfully noted that without working devices in the hands of real users we cannot know whether the concept of Fidget Widgets itself is truly sound.

Tactile / Tangible Experience

Reviewers consistently spoke of the tactile and tangible experience of items in their hands. This dominated all other commentary. Issues of pliability, softness, satisfying clicks, squeezes, and overall tactile stimulation arose repeatedly.

While some appreciated the form factor of the Sifteo cubes, it became clear that even the tangible experience of Sifteo cubes is insufficient for meaningful use of Fidget Widgets. This is not to say that the form factor should be abandoned. Rather, taken collectively, the reviewers' reactions indicated that the Sifteo cubes must be supplemented with a variety of other forms. For future incarnations of Fidget Widgets, we must move beyond the traditional computer form factor of electronics in a rigid box.

Sound

The audio experience of Fidget Widgets also garnered considerable feedback. Some reviewers were very interested in possible audio experiences, noting the creative personal music space due to headphones that facilitates their work. Others were quite concerned about annoyance.

Interaction Spectra

An envelope of an interaction design space emerged from our expert reviews. Apart from the preeminence of the tactile / tangible experience, feedback and reactions filtered into three broad spectra: Active Engagement–Passive Experience, Audio–Visual, and Personal–Social.

Spectrum: Active Engagement–Passive Experience

On the passive experience end of this spectrum, reviewers spoke about ritual, a desire for distraction from work tasks, and repetitive experiences. Note the desire for something "mindless" here (see discussion of survey results).

On the other end of this spectrum, reviewers spoke about a desire to support daydreaming, create stimulus to overcome mental blocks, and encounter new, ever-varied experiences.

Spectrum: Audio–Visual

Those reviewers on the audio end of this spectrum expressed a desire for no screens in interactions as an antidote to the screen(s) at which they stared while doing their work. Several spoke of the significance of music to their work process and to the personal workspace that headphones afforded. One reviewer referenced research done by Cliff Nass on the connection of music to creativity — specifically that new music is distracting while familiar music has been shown to aid creative work. Several reviewers spoke of the percussive nature of music and its connection to physically embodying a beat.

Those reviewers who gravitated to the visual end of this spectrum talked of animated GIFs and their fascination with creating flipbooks from stacks of paper. A reviewer suggested incorporating research on culturally significant shapes and colors to activate visual centers in the brain.

Note the rhythmic aspects in these descriptions of audio and video-based interactions. This echoes the descriptions of repetitive behaviors in the survey discussed previously.

Spectrum: Personal–Social

Many reviewers saw Fidget Widgets as a personal technology. Once again similarities to a personal workspace created by headphones were identified. Discussion of the personal connections workers form to their desk items was also raised. That is, designing to facilitate such attachments was important. Reviewers also expressed concern in protecting others nearby from intrusive noise.

Other reviewers saw Fidget Widgets as a social technology for fostering intra-office interactions and even encouraging childlike play patterns for sake of creativity and problem solving in group settings.

Expert Review Conclusions

From these expert reviews we draw significant conclusions:

- The concept of Fidget Widgets is compelling.
- Our previously unknown design envelope now has a set of boundaries in the interrelated active–passive, audio–visual, and personal–social spectra.
- A highly tactile experience is key. A development direction might entail embedding sensors in fiddle-worthy items of highly tactile materials. Data from these sensors collected wirelessly could drive interactions.
- Personality traits and learning styles may be connected to preferences situated along the identified design spectra.

CONTINUING AND FUTURE WORK AND CHALLENGES

We plan to continue iterating variations of Fidget Widgets in materials and form factors; in attributes selected from among our identified design spectra; and in permutations of reward, distraction, anxiety, disgust, motion, and audio and visual stimulation. With these variations we hope to selectively create mild positive and negative affect; develop and alleviate low levels of stress; temporarily consume attention or operate in parallel to a user's locus of attention; and engage the default network of the brain.

Material and Interaction Design Research

Our work has revealed the central importance of tactile and tangible experience in our concept. Our challenge is to arrive at configurations of materials and interactivity that yield satisfying in-hand stimulation and experiences.

To give us insight into these issues, we have made available online a data collection instrument[1] inviting public participation in our design process. We crafted our instrument to be shared via social media (with the hope of a certain viral effect) and to invite simple free-form photo, video, and text submissions as to items, fiddling manipulations, and sensations experienced in these acts. Though this is not rigorous scientific study, we expect to

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[1] http://fidgetwidgets.tumblr.com

identify meaningful patterns in material preferences, choices of objects / shapes, and behaviors employed.

Research Study Design: Experience-Sampling Method

Perhaps the most challenging work before us is to eventually structure studies able to establish modulation of affect and cognition toward measurably impacting creativity and productivity. As already noted, the intentionally tangential and incidental nature of these interactions compounded by their indirect inducement of user state change complicates any study design.

At present, our research design strategy is rooted in the Experience-Sampling Method (ESM) [33]. ESM is a longitudinal, field study approach that randomly samples study participants throughout the study period. Software is usually employed to generate user prompts (e.g. text messages / pages, emails, desktop notices, etc.) throughout the day at randomly selected times [7]. At each prompt a study participant completes a short instrument that captures activity and user state at the moment of sampling.

ESM is unique in that its random sampling yields good internal validity to the design while the in-the-wild nature of the approach simultaneously yields good external validity [9]. The obvious limitation is in the reliance on self-report compounded by the necessity for brevity of the self-report instrument. ESM has been enhanced with momentary video recording [13]; such an approach may work in our case and may successfully supplement self-report. A further challenge exists in selecting appropriate self-report instruments for each effect to be measured. Selecting study participants poses the standard challenges, but ESM affords us the opportunity to study the use of Fidget Widgets by real users in real work settings.

CONCLUSION

We introduced the concept of a physical margin space surrounding digital workspaces in which users often physically perform elements of their thinking in the form of doodling, fiddling, and fidgeting. We also introduced the concept of Fidget Widgets to be used in that margin as playful, tangible interactions. Fidget Widgets are intended to selectively modulate affect and shape cognitive state to support a user's productivity and creativity in their primary tasks. Work to create further Fidget Widgets in a variety of tactile forms and to study their effects on users is ongoing.

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