17. Improving Wearable Mindfulness App Through Participatory Design

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Abstract: Educators embracing technology to promote social-emotional learning (SEL) are rising in discourse. Successful SEL programs struggle to scale. Such technologies seek to broaden reach and improve quality through feedback, tracking, and guided practice. Despite generating behavioral and neurological changes, previous interventions have been based on practicing skills in a thin social context and are disliked by youth. Using participatory design, we redeveloped an SEL into a wearable technology. In collaborative workshops, youth revealed their interests in and models of self-regulation that we incorporated into a smartwatch app. Redesigning the application resulted in higher levels of satisfaction and more frequent use. A tension emerged around youth's desire for tools to increase self-regulation without adding stress. While youth valued breath counting, they reported development of self-regulation through pursuits such as gaming. An interest-driven approach may leverage breath counting as attention-focus practice but competes with activities (sports, hobbies, academics) for youth time.

Introduction

Noncognitive skills such as grit, tenacity, and perseverance have captured public imagination, as evidenced by Duckworth's (2016) *Grit: The Power of Passion and Perseverance*. Noncognitive skills predict general success across domains and are referenced in academic achievement (Farley & Kim-Spoon, 2014). Grit, tenacity, and perseverance are associated with the umbrella term *self-regulation* (SR), which is the enactment of behavior to monitor and regulate one's activities (Dweck, Walton, Cohen, Paunesku, & Yeager, 2011). Self-regulation represents (a) a host of skills that can be developed, (b) strategies that may be deployed in variable contexts, and (c) a resource that can be drawn upon (or depleted) through use. On a conscious level, for example, SR may be recognizing an angry feeling and diffusing it by enacting a calming strategy. The capacity to regulate one's self (social, emotional, and behavioral) has crucially been demonstrated to support academic and social development (Bodrova & Leong, 2007; Diamond & Lee, 2011; Raver et al., 2011). Diminished SR capacity creates difficulties directing attention, managing social problems, and learning.

Educational Methods for Improving Self-Regulation

SR can be trained to affect the capacity of one's self-regulatory behavior. Targeted activities have been shown to train executive functions (EF) and improve EF and SR assessment (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). However, isolating and training EF to promote overall SR is limited by context; transfer of learning from single EF often fails to transfer to untrained tasks (Rossignoli, 2018). Transfer of EF training onto untrained tasks has involved extended activities situated in complex environments (Diamond, Barnett, Thomas, & Munro, 2007). Interest-driven activities that emphasize planning and reflection, such as fitness or academic planning, have provided examples of EF transfer for untrained tasks (Oaten & Cheng, 2006). Successful EF programs include connected learning; they introduce EF explicitly, address EF across activities, occur over extended time, repeat throughout the day, provide progression through increasing challenges, and often include mentorship (Diamond & Lee, 2011; Lakes & Hoyt, 2004).

Game-Based Models of Self-Regulation

Game-based interventions offer models for managing self-regulation (Owen et al., 2010). *Luminosity* and *Elevate* show gains across cognitive tasks (Garcia, 2004; Nakano, 2015). Trainers such as *CogMed* employ game-based metaphors and SR training programs based on commercial games (such as *Super Monkey Ball* and *Brain Age*) demonstrate nearly half of a standard deviation improvement on IQ tests (Hardy et al., 2015). Commonly, SR cognitive training tools are based on clinical cognitive tests, making the intervention a form of "test taking" training (Mallan, Singh, & Giardina, 2010). *Breath counting* games can improve self-regulation (Kral et al., 2017). A two-week period breath-counting intervention improved attentional self-regulation as measured by behavioral tasks and neurological imaging (Patsenko et al., 2019). Evidence for physical brain changes over two weeks suggests breath counting may be a high-leverage psycho-sociological intervention (Yeager & Walton, 2011). Situating the above game within a robust social context could increase appeal and promote social or metacognitive practices associated with transfer (Rossignoli, 2018).

Personalized Tracking for Self-Regulation

Personalized tracking can improve the regulation of attention (Michie et al., 2011). Through personalized trackers, users can collect, visualize, and share data (Kim, Jeon, Lee, Choe, & Seo, 2017). Trackers can detect behavioral markers, opportune moments for intervention, and context-sensitive interventions (Epstein, Kang, Pina, Fogarty, & Munson, 2016; Gouveia, Karapanos, &. Hassenzahl, 2015). Trackers may be improved by designing for levels of readiness, goal setting, and sustained engagement. Tracker users rarely consult past data, and in one study, only 30% of users set daily step goals; fewer updated their goals (Epstein et al., 2016; Gouveia, Karapanos, & Hassenzahl, 2015). Trackers may work best for intermediary behavior change; those in other stages such as pre-contemplation, action, or maintenance use them less. Trackers benefit by being designed for specific populations doing specific tasks along a trajectory of activity.

Participatory Design With Youth

Participatory design represents a sustained engagement between designers and stakeholders that seeks to create more usable products while understanding the context of use and leveraging participants' tacit knowledge. Participatory design includes: (a) *explorations* (interviews, discussions, and observations), (b) *envisioning* (storyboarding, role-playing), and (c) *prototyping* (Spinuzzi, 2005). The most compelling situation for successful participatory design involves sustained collaboration through time (Brandt, Binder, & Sanders, 2012). During design activity, youth may require remediating skill gaps and explaining design context (Druin, 2014).

Methodology

The design-based study included three phases: (a) a participatory design workshop in which youth redesigned a breathing app for wearable technology, (b) a design enactment that leveraged features and practices youth routinely engaged in, and (c) a naturalistic study of how youth used the collaboratively designed devices.

Research Questions

1. How do youth conceptualize self-regulation into designs, explanations, and artifacts?
2. What features do youth desire in wearable self-regulation technologies?
3. How do youth use wearable technologies for self-regulation?

Participatory Design Workshop

Participants. Twenty-seven youth from a low socioeconomic status middle school participated in seven 90-minute afterschool workshops in which they designed technologies for self-regulation. Youth were between ages 11 and 14 years old and compensated with lunch and a $30 gift card. A participant-researcher led each session with one to three participant-observers to take notes and lead small-group activities (see Figure 1). Small group activities were recorded with a video camera and audio recorder. Workshops began with a short 10-minute self-regulation training exercise (Patsenko et al., 2019).

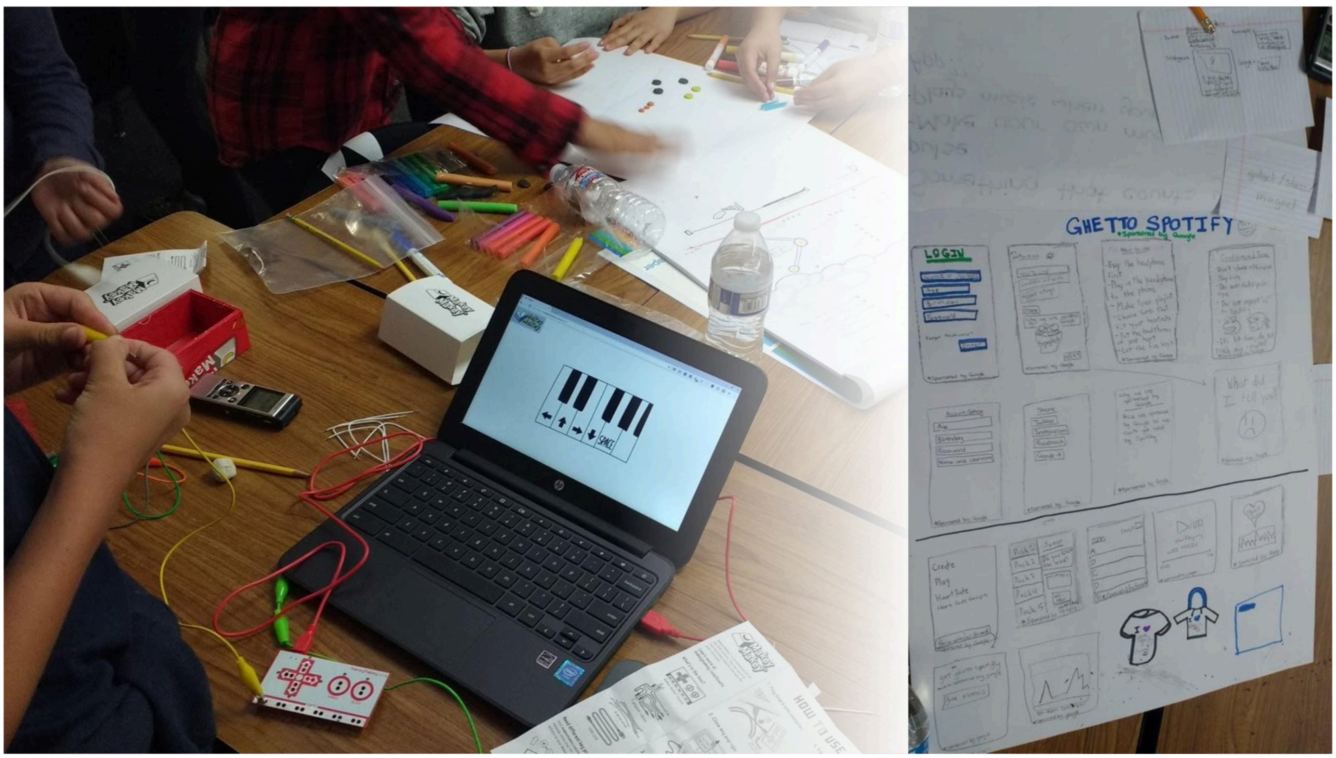

Figure 1. Student prototypes integrated biofeedback data, customized lists and goals, and the ability to share playlists of music useful for concentration, as well as rhythm games for concentration.

Youth design activities. Our design activities built upon previous participatory design workshops for LatinX youth and were presented as challenges intended to guide participants' activity (Vacca, 2017). A few challenges were to *Make a Game Prototype*, *Merge Multiple Ideas Together*, and *Storyboard an Idea*. Challenges guided activity and were not intended to formally teach or instruct about design. Youth produced the following designs: (a) a *space exploration* game that used mini-games to train focus, (b) an employment scenario game in which players managed distractions, (c) a fidget device that integrated multiple user inputs and outputs (toggles, clickers, sound), and (d) a music game in which players matched tones to follow a displayed pattern. A second design round focused on wearable devices and produced: (a) a heart-rate tracker that responded during moments of stress, (b) physical finger puppets to manage stress with a supplementary software application, (c) a white-noise device with music and rhythm elements, and (d) a support tool that assists in scheduling activity, logging achievements, and organizing competitions.

Analysis. Researchers convened after each session to identify themes and adapt workshop activities. Themes were recorded in a shared data repository with accompanying notes on groups or data sources to facilitate later analysis. After the workshop, researchers reviewed audio recordings and design artifacts and chose key events to examine in depth and transcribe. We present our findings as warranted assertions to answer our research questions (Stake, 1995).

Results: Youth Designs, Artifacts, and Explanations

Youth (a) valued designing SR apps and (b) discussed strategies for managing stress and focus with sophistication. Youth reported enjoyment in exploring new friendships and experiencing others' points of view throughout the design activities. Youth, however, did not thoroughly enact social mechanics in their designs and largely focused on the immediate actions relevant to a single player or user (see Figure 2).

Youth explicitly referenced self-regulatory behaviors in response to their homework. Jasmine used music to induce a "hard working" mood, which was common. Wyatt shared that stress motivated him to work hard and focus— a view similar to the Yerkes-Dodson (1908) law. Wyatt connected stress to biological markers and wanted data on such markers: "if you're stressing out and your heart is racing, then a metronome may help you realize you're stressed and calm down to refocus."

Youth used music to augment SR. Music was cited as a motivational tool, mood setter, and ally for channeling stress, although it has not been thoroughly studied in the SR literature. Music does not train SR but counteracts depletion effects (Baumeister & Vohs, 2003). In addition to *training* SR, researchers might give youth tools to *improve* SR capacities; youth were more interested in augmenting performance than training SR. Youth described SR primarily as motivation or energy and sought tools that augmented their current functioning and performance.

Proficiency in SR design activities. Youth design demonstrated a readiness to engage in difficult challenges and sophistication in enacting higher-order collaboration. They reviewed games, proposed ideas, created artifacts, and iterated plans while managing group cohesion. Teams made storyboards and interface mockups with little instruction or prompting. They demonstrated tacit knowledge of user interfaces (UI) and onboarding experiences (e.g., email, profile setup, user details). Teams implemented roles without our instruction and included note takers, illustrators, constructors, and voice leaders.

Figure 2. User interface mockups for a rhythm game. Student designers are playing with musical notation-based interface systems, similar to popular rhythm music action games.

Gameplay, mechanics, and transfer. Youth wrestled with the context-dependent nature of self-regulation and transfer into untrained scenarios. Youth entertained grand ideas during initial brainstorming (e.g., Spotify clone; see Figure 1) but pruned them for designs achievable given our limited number of workshops. The designs resembled communities with abstract support around SR topics, instead of directly targeting SR improvement through specific activities. To use a martial arts metaphor, youth were more interested in creating dojos than training specific moves. While youth demonstrated an eagerness to approach complex software design, they often did not have the experience to guide themselves through the process to obtain a focused and specific SR trainer.

Social interaction design. Another design gamified the quantified self on a community level. Players would compete against other *teams* similar to FitBit "step count" challenges by monitoring their application usage. For example, *Team 1* would win if their total time spent watching YouTube was lower than *Team* 2's. Competitions within this design included time on homework or player-defined contests (e.g., physical activity). Caspar said, "The competition makes you want to use it more, but there should be a beginning with a time limit that everyone needs to follow."

Youth value social investigations about themselves and design. Youth worked past the time allotted and expressed an interest in additional design sessions. The level of engagement suggests: (a) youth valued reflection on mind, body, and being, and (b) design-based programs are an engaging format of learning and experience alternative to traditional curriculum activities. *Situating users as designers of their own emotional regulation routine may be a guiding metaphor for the domain.*

Findings and Design Guidelines

1. **Youth understand SR, value its development, and expressed interest in tools to improve it.** *Recommendation*: Explore design metaphors using emotional regulation routines that explicitly focus on improving and strengthening SR.
2. **Youth identified personal SR challenges and described strategies for improving performance.** *Recommendation*: Incorporate timers, scheduling features, and consider integrations of commonly used applications (e.g., music).
3. **Youth connected physiological responses to SR experiences.** *Recommendation*: Integrate physiological sensors as appropriate and provide tools for self-monitoring.
4. **Youth expected gaming conventions to be employed in SR tools.** *Recommendation*: Games are strongly associated with opposing reactions to calm and meditative breath counting but provide a strong motivation for youth and should be considered in the design of their SR tools.
5. **Youth demonstrated interest in discussing SR challenges with peers but hesitated to share data.** *Recommendation*: While protecting individual privacy and desires to share, opportunities to help students feel comfortable sharing their information may be needed to facilitate communal behaviors.

Study 2: Redesign

Tenacity evolved to be a breath-counting community (Lakes & Hoyt, 2004) centered around *Tenacity* for the Apple Watch, which included a breath-counting application (*Breathe*), a pattern-matching game (*Lotus*), and a rhythm-music action game (*Rhythm Tap*) integrated through the iPhone (see Figure 3). We also included *Breathe Infinite*, in which youth breathe without session limitations and goals. This study follows a field-deployment schedule from convenience sample, to semicontrolled study, to in-the-wild study. The later studies contained a battery of cognitive measurements (Siek, Hayes, Newman, & Tang, 2014).

Figure 3. Tenacity Apple Watch interface: Apple Watch selection menu, Lotus pattern-matching game, Breathe game, and iPhone companion app.

Participants

We recruited 35 participants between the ages of 11 and 15 across three events in two states. Participants were selected to round out the target demographic (at-risk middle school youth) rather than randomly sample a population (Rubin & Chisnell, 2014). The second out-of-state site broadened the user pool beyond our local at-risk selection.

Procedure

Each participant was given an Apple Watch and an iPhone, introduction to the software, and overview of the study. They were asked to naturally use *Tenacity* for two weeks. Whereas previous studies *required* use, we desired to observe how youth used *Tenacity* outside of compulsion or strong financial incentives. At the end of the two weeks, they completed a questionnaire and one-hour semistructured interview. Sample questions included: How often did you use *Tenacity*? When and where did you use *Tenacity*? What was using *Tenacity* like?

Findings

One third of the participants used the app at least once per day (12), some even multiple times in a day (9). Students' self-report claims matched analyses of log files (see Figure 4). Eighty percent of participants (29) used the app after school hours while in transit, idle, bored, after exercise, before bed, and while doing homework. Only three participants used the app in school. Forty-five percent of participants (16) reported using *Tenacity* to calm down. One participant stated, "I use *Breathe* … because I had to help my dad outside a lot and I got really [stressed out]. … Sometimes I use it like three times a day. Mostly because I get really [mad]." No participant mentioned using *Breathe* as an exercise application. Youth desired to strengthen attention but did not set out time for it explicitly.

Eight participants reported sharing the app with others. Participants did not report meeting each other in person to play. We released *Tenacity* with cohort groups, hoping to seed competition or cooperation, but such events were uncommon. A few reported competitions with *Lotus*, as one youth commented, "When we use *Lotus* we would be competing to see who can get like the fastest time to swipe." Only two suggested social-interaction improvements, compared to 33 app-centered improvements such as customization or rewards.

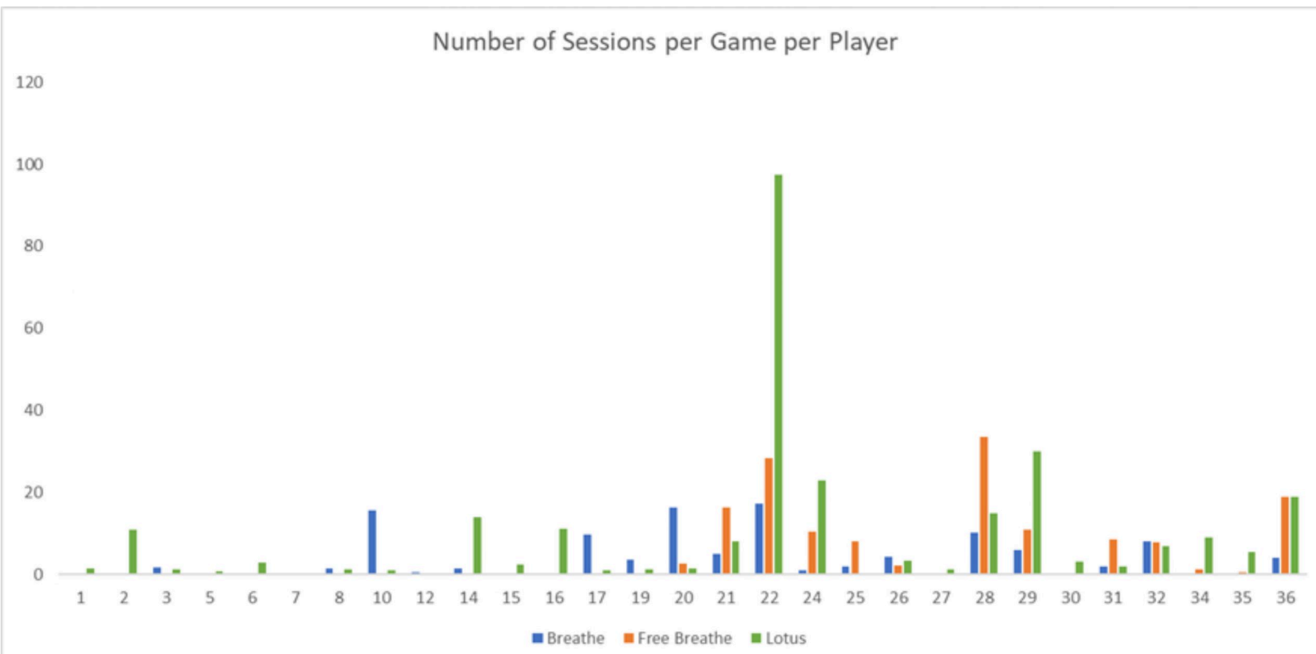

Figure 4. Number of sessions per game per player. Individual users are displayed on the x-axis (n = 36). Total number of sessions for each game played by user is on the y-axis (n = 120).

Redesign Results

Youth responded positively to the redesigned wearable version of *Tenacity*. Comments were positive (whereas previous responses suggest non-use outside of the study). A subset of participants particularly valued the application as a daily tool. *The primary interest was in using* Tenacity *to relax and calm down.* Youth reported that *Tenacity Breathe* was useful for relaxing and focusing attention before homework. It was used in the mornings, between classes, and before sleep (or waking up during the night). After school was the most popular time to use the application, with another spike is usage seen before bedtime.

Being able to organically train SR is a high priority. Youth were interested in training SR in the service of other activities but *less* interested in SR training as the activity itself. Youth *already* have engaging and fulfilling digital experiences, *some of which are likely training SR as a byproduct of challenging scenarios*. As Apolonia said, "You can't tell it's a game made for something, it's a game made for fun. I don't have to play this game to practice my focusing skills." Awareness of research may create indigenous critiques on why youth need more interventions.

Youth demonstrated interest in collaborative play. Youth reported occasionally racing during the *Lotus* pattern-matching game and handing off devices to friends to watch them play. There was not, however, a strong desire to complete joint achievements; youth were reluctant to collaboratively play the *Breathe* game. We caution against overgeneralizing, but for this audience, breath counting was seen as a private experience and a method of relaxing.

Youth want their personal information kept private. Using *Breathe* was a distinctly *private* act. Privacy was mentioned in interviews as an obstacle to collaborative play. This suggests a need for a system in which players selectively share play behaviors yet keep control on what information others can access.

Discussion

Increasing Engagement Through Wearable Technologies

SR training has followed a medical science paradigm in which a static, uniform intervention is compared to a control to support research findings. These foundational studies, which have found positive effects, also report alienating students because of the disengaging focus on the "training" aspect of SR development. Youth shared concerns about stress and anxiety and an openness to approaches that build on their own mind-focusing techniques. They reported nontrivial amounts of stress (which is echoed in popular media) and are eager to discuss these issues with peers. Wearable tools that help are largely appealing.

Future Directions: Biological Markers, Tracking, and Sociability

Youth valued opportunities to monitor and view biological markers or the allocation of their time throughout the weeks. Youth also advocated for competing among friends toward targeted behaviors. Yet youth did not readily form SR training communities (Epstein et al., 2016). *Tenacity Breathe* focused its design on a *private meditative experience*. There were isolated incidents of youth coordinating their breath counting, and a few turned it into a cooperative experience, but these were exceptions. Given that executive functions are robustly trained within rich sociocultural activity, finding ways to develop and nurture communities of some sort (SR training, Breath Counting, Meditation) may lead to organic and more easily supported SR development.

Scaffolding Youth Performance Versus Training Underlying Skills

The primary interest has been to use Tenacity *to relax and calm down rather than train mindfulness as an underlying skill.*

Emphasis on increasing performance rather than training faculties suggests a paradox for designers; on the one hand, youth want to increase their attentional faculties, specifically, capacity to remain calm in the face of social and school stresses. On the other hand, students have resistance to targeted training and desire a low-stress experience. Social and academic stresses deplete SR and will require users to prepare to expend additional resources in order to improve. Youth want, and are willing to use a relaxation device, but they do not want another thing to stress about.

Conclusions

We should reflect on the design assumptions of youth mindfulness tools. While youth are eager for tools and interventions that reveal their physical and emotional states, they are like every other member of society. Youth must approach and overcome daily challenges and stresses in a hypercompetitive environment. Are our efforts best placed in developing SR training apps? Should we instead make structural changes to achieve equitable and supportive systems that better prepare students for success? The rise of attention on individually psychologized paradigms such as grit and tenacity, rather than on the underlying social structures that contribute to them, may lead to a scenario in which those who are struggling continue to fall behind. One possible interpretation is that breath counting and mindfulness training are components to a necessary and larger systematic overhaul. SR trainers can be presented as tools to reduce stress and improve executive functioning, so long as they are implemented in a way that fosters understanding and remedying the social conditions that produce discrepancies between SR and achievement. One such use may be ongoing assessment and evaluation in order to identify and provide support to individuals in need.

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