The Effects of a Fidget Cube With an Integrated Ambient Display on Office Workers

Lucas Schmieder*
lus8199@thi.de
Technische Hochschule Ingolstadt
Ingolstadt, Germany

Sofia Borejko*
sob4250@thi.de
Technische Hochschule Ingolstadt
Ingolstadt, Germany

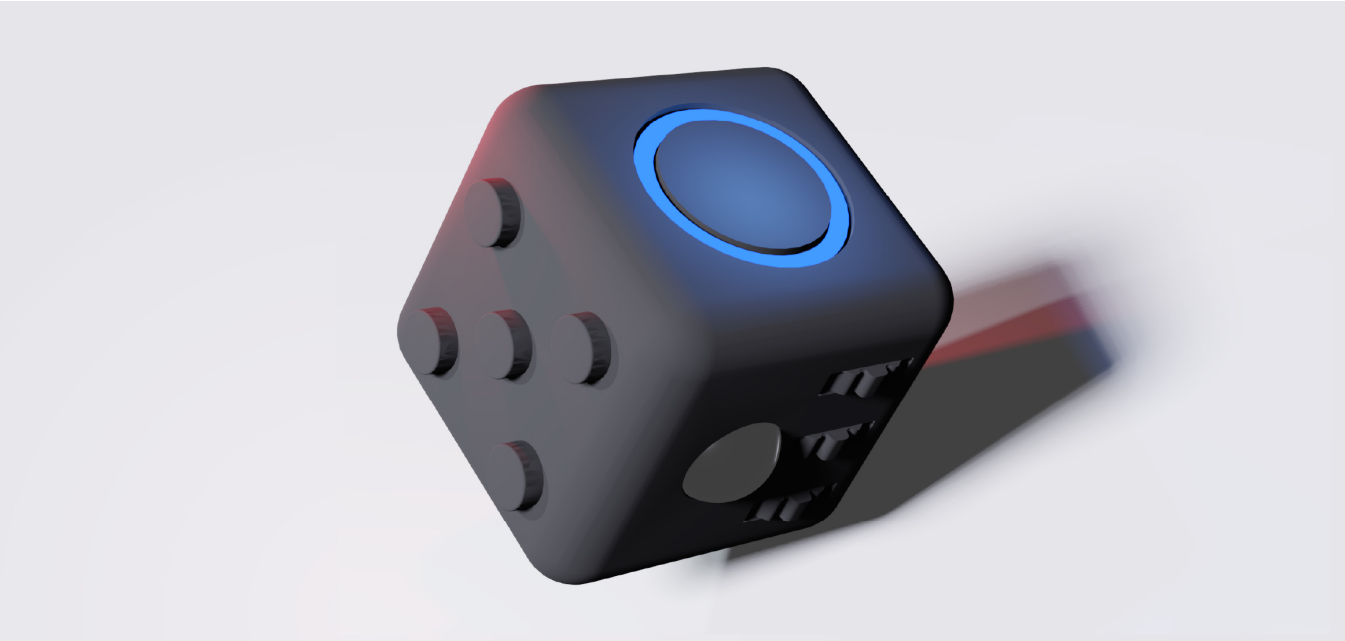


Figure 1: Concept Render Of a Fidget Cube With an Integrated Ambient Display.

ABSTRACT

The visualization of biofeedback through ambient displays has been the subject of research for some time. As have investigations into the instrumentalization of fidget toys for performance optimization. We see great potential in the combination of these two concepts and present the first implementation in the form of a prototype. With a general online questionnaire, we analyzed the target group and explored the first iteration of our concept. With an exploratory study, we aimed to identify the impact on mindfulness, the influence on self-perceived performance, interaction, and overall satisfaction. With this research, we build the foundation and give practical instruction on the design of the ambient light and discuss its use in the office environment in terms of appropriateness and social implications.

KEYWORDS

Biofeedback, ambient display, fidget toys, office workers

1 INTRODUCTION

With increasing globalization and digitization, humans face more and more challenges in different fields of their life. More so, our work-life is changing rapidly with a rising trend towards "new work" as suggested by Frithjof Bergmann [3]. Today's full-time employees are attracted to job offers where they are able to manage their private life and work-life to their liking [5]. But Matta's research suggests that this working time model may lead employees to work more hours than determined in their contracts [16]. Kersten et. al found in their research that socio-psychological work conditions in cognitively demanding jobs lead to significantly higher burn-out scores [9]. Also, people who work significantly more hours, report more health issues, a generally poorer health condition, a decreased work satisfaction, and poorer work-life balance [27].

A Report from the "Bundesanstalt für Arbeitsschutz und Arbeitsmedizin", an administration for occupational safety and health in Germany, shows that jobs in the industry and larger companies offer more flexible working hours [27].

With the fast pace of our lives and the increasing workload, people turn more and more to self-help products and services. Under that fall alternative medicine, courses both offline and online (e.g. Yoga, Pilates), self-help literature, and much more. According to Google Trends, the term "self-care" experienced a dramatic increase in popularity in the last 5 years. People feel the need to relax from stressful work experiences.

*Both authors contributed equally to this research.

Meanwhile, fidget toys have been heavily in the eye of the public in early 2017, when the fidget spinner found its way into many schools. In the U.S., fidget spinners and other toys were gaining rapidly in popularity until its peak in May 2017, according to Google Trends. This raised many voices of concerned parents and annoyed teachers, which lead quickly to fidget toys being banned across most of the schools. However, in kids with sensory issues and attention-deficit/hyperactivity disorder (ADHS), fidget toys have shown to have a beneficial effect on attention and well-being, according to Zentall [29].

Fidget toys are broadly discussed and researched in the field of psychology. Stavley and Brasell's research suggests that the use of fidget toys in a classroom setting can improve students' performance, satisfaction, decrease restlessness and the need to distract other students, and increase the overall classroom environment with the teacher also being positively affected [23].

We wanted to explore the effects of a fidget toy equipped with an ambient display on office workers and address with that the problem of over-stimulation. We wanted to find out: Can fidget toys with an integrated ambient display support the user by improving their performance and overall satisfaction? We formulated three hypotheses:

- H_1 The system supports the user in regulating their emotions more efficiently.
- H_2 The overall perceived ability to focus on day-to-day tasks can be significantly increased with the help of the system.
- H_3 The use of an integrated ambient display represents a suitable solution.

2 RELATED WORK

Our presentation of findings from related work is divided into three main concepts that we want to combine in our present study.

2.1 Fidget Toys and the Effect of Facilitated Fidgeting

Natural Fidgeting is a behavior that people show naturally, often unconsciously, and without the help of aids or objects. Building on Kriescher's [11] distinction of fidgeting behavior into facilitated fidgeting and natural fidgeting we want to explore in this study the opportunities and possibilities of facilitated fidgeting. In this context, we will use objects that are grouped under the umbrella term "fidget toys" and whose sole purpose is to play one-handed, without focus, in order to support primary cognitive tasks. In her work, she investigates its use in an educational setting using college students' performance on a range of attentional and cognitive tasks that occur during different learning processes. Her results showed little to no effect on academic performance.

A positive effect on attitude, attention, writing skills, and social interaction was found by Stalvey and Brasell [23] when they observed sixth graders for 10 weeks before and during the use of a stress ball in their daily school routine.

After reviewing existing scientific literature, the effectiveness of fidget toys cannot be sharply defined in a general statement. Too little research has focused on the effectiveness of fidget toys or fidgeting in general outside of an educational context, and the respective target groups are too limited to make general statements about the overall benefits beyond the developmental span from childhood to early adulthood.

In 2016 a research team asked people to photograph, upload and comment on objects in the physical environment of their workplace they played with while performing primary tasks [8]. On one hand, this resulted in a remarkably large database of images that can be used to derive important design aspects [1]. On the other hand, the evaluation of the comments revealed that descriptions such as *"satisfying"* and *"pleasuring"* are related to the aesthetics of highly stimulating materials and tactile experiences. Many participants talked about the active modification of their inner state in connection with the use. So there are hints that facilitated fidgeting is already being actively used to control emotions. Due to the preceding partly contradictory theories and uncertainties, and the lack of conducted studies on the effect of fiddling on emotion regulation, we see great opportunities for facilitated fidgeting in this area.

2.2 Ambient Light Displays

In order to approach ambient displays, several definitions have already been compiled [13] from which a number of points can be derived to characterize ambient displays: Low cognitive load, aesthetically pleasing, integrated into the environment, perceptible in the periphery of attention, and unobtrusive. In addition to the possibilities of transmitting information through temperature, smell and sound, the possibility of an ambient light display was particularly interesting for us.

Light is an ideal data transmitter because color, brightness, and intensity can be linked to intuitively understood information. Color-psychological properties have an additional effect on people. Ross et al. showed in their study that specifically, a warm-colored light (red, orange, yellow) can have an alarming and energizing effect on the organism, while a cool-colored light (green, blue, indigo) makes people feel calmer [6, 22]. Although many papers deal with the psychological effects of light, most of them deal with the effects of light on the retina and the hormonal processes triggered by it. The comparatively small light source of the ambient light, therefore, has more of a secondary effect. In this study, it should be understood primarily as an information carrier and not as an effector in its own right.

2.3 Biofeedback

Biofeedback primarily enables users to become aware of unconscious body signals, evaluate them and, if necessary, adjust their behavior accordingly to ultimately improve health and performance. Biofeedback has already been used for 40 years in the health sector for the treatment of anxiety disorders [21] and post-traumatic stress disorders [12]. Now, the development of new technology is making its use possible in the private sphere. This trend is called ubiquitous biofeedback [1] and allows users to incorporate active health and stress management into their daily lives at the office, gym, or home. For this purpose, parameters such as pulse, skin conductance, and muscle tension are measured, processed, and presented to the user, usually by using additional measuring devices on the body. Often, the object that is ultimately to be used for regulation also functions as a measuring device like the BioFidget device [14]. We chose a

[1] https://fidgetwidgets.tumblr.com/archive



(a) Concept Photo (b) Concept Art (c) Concept Render

Figure 2: Various Concept Images to Illustrate the Look-and-Feel of the Fidget Cube With the Integrated Ambient Display

smartwatch for biosignal measurement in our concept (see section 3) because many people already wear them anyway and they do not represent an additional disturbing element at the workplace. Watches have no issues with social acceptance, are even considered a status symbol, can provide the necessary power for the processing without upgrading, and are already equipped with a number of sensors for measuring biodata. The authors of the DeLight study [28] used heart rate variability (HRV) for their stress reduction system in conjunction with biofeedback, which is considered the most widely used technique in stress management [26] and enables active user stress management. The HRV data can be calculated from the heart rate and easily measured via photoplethysmography (PPG) sensors over the user's fingertip or earlobe.

3 CONCEPTUAL DESIGN

To exhaust the potential of both facilitated fidgeting and mood-regulation over biofeedback, we approached our study combining the two following components:

(1) Fidget Cube with an integrated ambient display
(2) Smartwatch wearable

3.1 Fidget Cube With Integrated Ambient Display As a Concept

Choosing a Suitable Fidget Toy. There are many fidget toys out on the market to suit everyone's needs. They come in all varieties, different forms, colors, textures and functions. With the exploratory study in mind, we chose the Fidget Cube because of its variety in functions, elegance, not toy-looking appearance, and especially - its space inside. Although a single RGB-capable LED and a wireless transmitter would not take too much space, for our purposes, the Fidget Cube was the ideal choice. The Fidget Cube was introduced in 2016 on the American crowd funding platform "Kickstarter" and was one of the most successful campaigns with an overall fund of 6.4 million dollars [18]. Usually, the cube comes with six dedicated sides and one function each. Those include: clickable buttons, a joystick, a rolling ball, a switch, a smooth stone side, three cogs, and a wheel. For our prototype, we sacrificed the joystick in order to install the ambient light. For the final product, it has to be evaluated which side on the original Fidget Cube is the least favorite to swap for the ambient light. This is subject to further design considerations and was therefore not focus of this study.

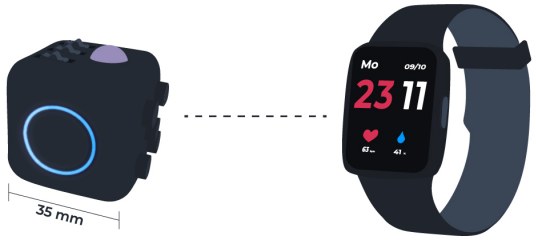


Figure 3: Concept Image: Fidget Cube Connected via Bluetooth to a Smartwatch as the Preferred Device for Biofeedback Measurement.

Functionality and Use of a Smartwatch. The LED light ring on the fidget cube functions as the interface between the user and the cube software. Additionally, the system is intended to be compatible to the most common models of wearables — primarily smartwatches. A smartwatch is needed to track the biosignals of the user to then react accordingly. Under the required biosignal sensors falls a heart rate monitor, a blood pressure monitor, a skin conductance sensor, and a skin temperature sensor. Those sensors combined can be used to achieve a somewhat precise depiction of the user's emotional state and stress level. Kapoor's research on recognizing affection suggests that the posture of a person also plays an important role in assessing one's emotional state [7]. For the sake of simplicity, this concept will neglect the effect of posture, but can be subject to further scientific investigations.

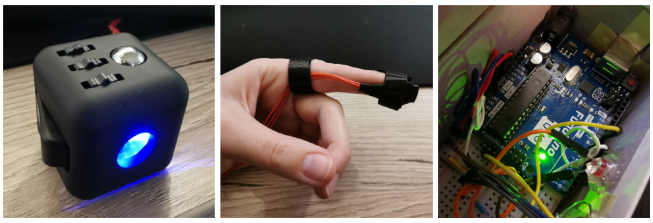
Requirements. For the concept of the cube, we have defined several requirements in terms of functionality and interaction.

- Smartwatch tracks the different biosignals to form an estimation of the user's emotional state and stress level
- The LED in the cube gives feedback on the tracked emotional state and stress level in the form of different light colors and patterns
- If the emotional state or stress level goes above a predefined threshold, the cube will trigger a "Play With Me"-light animation to indicate that the user is under emotional tension
- Further, the light pattern and color has to adjust to the estimated emotional state to inform the user, not only that they are under some tension, but also specify what that tension is

To know, which colors should be assigned to which emotions, we conducted an online questionnaire that will retrieve the participants intuition. More information on the questionnaire can be found in section 4.

3.2 Implementation for Exploratory Study

The current concept for the Fidget Cube with an integrated ambient display brings challenges in terms of technological feasibility and can not be realized, as it is, yet. To test the concept in a real-life scenario, we adjusted the base requirements to the technological



(a) Fidget Cube Prototype (b) PPG Sensor (c) Main Console

Figure 4: Overview: Hardware Components of the Prototype

feasibility, experimental conditions, and the available time frame, keeping the essence of the original concept. This section addresses differences to the actual concept that arose as a result.

Biofeedback. The software of most smartwatch manufacturers whose hardware includes the sensors we need is only available as a closed system. Reading out the data we need requires cooperation with manufacturers, which we do not have for this exploratory study. To get around this problem, our prototype works with a commercially available photoplethysmography sensor from the company ICQUANZX [2], which we use to measure the pulse as an indicator of internal arousal states. Further processing steps are implemented with the help of an Arduino One.

Ambient Light. An important part of the online questionnaire is the assignment of colors to certain emotional arousal states. The possibility of displaying different emotions in color-coded form via an ambient light is not yet given. Nevertheless, we have implemented blue as the only signal color because of its proven calming effect [22]. If a threshold of $bpm \geq 90$ is crossed, the cube lights up in a blue, pulsing pattern that fades over time until it goes dark. If the heart rate was still above the threshold, the animation would start over again. It was not possible to implement a direct dynamic light response to the heart rate, as the sensor's signal was not steady between two short time spans.

Connectivity. To accomplish a wireless interaction between cube and console, a radio transmitter would have to be built into the prototype. To achieve that, a whole new, bigger outer shell for the cube would have to be 3D-printed in order to fit all necessary electronics. Due to the small time frame, that was not feasible. This will play a big role in the user experience and was addressed in section 5.3.6. Therefore, the prototype for the exploratory study communicates via cables between Cube and Arduino, and PPG and Arduino.

4 EXPERIMENTAL DESIGN: ONLINE QUESTIONNAIRE

To get a full understanding of our concept, gain insights on our target group and their pains and gains, we conducted a survey in the form of an online questionnaire. Because the prototype deviated somewhat greatly from the original concept (see section 3.2 for more details), it was necessary to test the hypothetical concept with a separate group of individuals, who were not primed to the prototype.

4.1 Procedure

Before filling out any questions, participants were informed about ambient lights, fidget toys, the purpose of the study, and an explanation, how the interaction with the Fidget Cube with integrated ambient display works. Participants filled out a questionnaire that takes about 10-15 minutes. The questions were in the form of a Likert scale (1=*"low/negative"*, 5=*"high/positive"*), but also contained open questions for further qualitative analysis.

4.2 Participants

For this survey, 31 participants between 18 and 60 years old volunteered (16 males, 15 females). Volunteers were mainly recruited from the social and working network. However, there were also some fellow students from the "Technische Hochschule Ingolstadt", Germany, who were willing to participate. The students were compensated with our participation in a study of theirs. Participants from the social and working network were not compensated except for an expression of our gratitude.

4.3 Results

If not explicitly stated otherwise, a Shapiro-Wilk test shows a significant deviation from normal distribution with $p < 0.05$. The concept of the Fidget Cube with an integrated ambient display of this study may be referred to by *"the system"*, *"the cube"* or *"the fidget toy"*.

4.3.1 Target Group Analysis. With the online questionnaire, we were able to gather new insights in the following fields:

- perceived influence on one's performance and focus
- acceptance and stance on fidget toys
- design concept and further considerations

For our target group, we specifically chose office workers and students from the age of 18 upwards. The target group was analyzed further to learn their pains and gains, habits in work life, and the stance on fidget toys. In later design stages of the product, this information could be used to refine the concept and generate personae.

The participants of our study were mainly 25-30-year-olds (48.4%), whereas 22.6% were 18-24 years old, 6.5% 31-35 years old, 9.7% 36-40 years old, and 16.1% 56-60 years old. From that, 58.1% of participants were in employment, while 41.9% were students.

As expected, most of our participants spend over 7 hours per day behind their desks (29% 7-8 hours and 29% more than 8 hours). While 90.3% do not own any fidget toys, 9.7% stated to own a fidget toy of any kind (3 participants owned a Fidget Spinner, one participant owned a Rubik's Cube and one participant owned a rotating cube).

The questionnaire also asked for their stance on fidget toys in general. Participants were able to chose between *"useless toy"*, *"a distraction from actual work"*, *"neutral"*, *"good to have, but not necessary"*, and *"I can not even begin my work without one"*. Most participants had a neutral stance on fidget toys (40.6%), whereas 12.5% participants answered with "a distraction from work", 25.0%

[2] https://www.amazon.de/gp/product/B07VJ9XB7T/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1

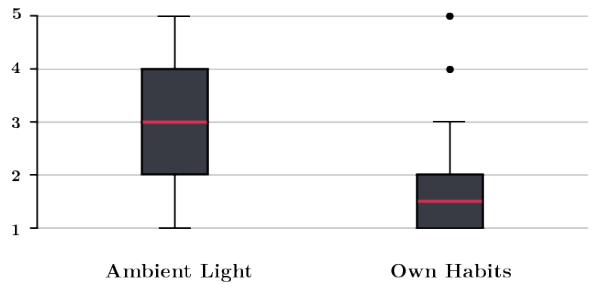


Figure 5: Graph for Disturbance of the Ambient Light on the Cube to Colleagues (Left) In Comparison to Disturbance of Own Habits to Colleagues (Right)

with *"useless toy"*, and only 21.8% stated *"good to have, but not necessary"*. None of the participants were seeing a fidget toy as an absolute necessity.

4.3.2 Perceived Performance and Focus. Since the participants of the online questionnaire were only left with our written concept and some concept pictures (see Figure 2), it was not possible to test whether the Fidget Cube with an integrated ambient display had an actual impact on performance and focus of users. Instead, the questionnaire asked for an estimation from participants and if they can picture the system having an influence on their performance and focus in everyday tasks. The questions for assessing influence on performance and focus followed a 1-3-5 scale (1=*"low/negative"*, 3=*"neutral"*, and 5=*"high/positive"*). A one-sample Wilcoxon signed-rank test against the value $\mu_0 = 3$ was therefore performed. Running a two-sided test showed no significance for both variables (performance: $p = .461$, focus: $p = .675$).

4.3.3 Acceptance. Under the acceptance fell multiple variables: Stance on fidget toys, suggested reaction from colleagues to the acquisition of a fidget toy, the perceived disturbance of the light on the cube to colleagues, the disturbance of the light on the cube to oneself, and lastly, the perceived disturbance of own habits to colleagues. The questions *"Do you think colleagues might feel distracted/disturbed by the light on the fidget cube?"*, *"Would you feel distracted/disturbed by the light on the fidget cube?"*, and *"Do you think colleagues feel disturbed by your habits?"* were in the form of a Likert scale (1=*"Not distracted/disturbed at all"*, 5=*"Very much distracted/ disturbed"*) and therefore comparable. Except, there is no neutral position in this question, since the semantically neutral position is missing between *"not disturbed/ distracted"* and *"very much disturbed/ distracted"*. Because of this, these variables can only be compared between themselves.

We first compared the *disturbance of the participants own behavior* ($Med = 1.5$, $IQR = 1.0$) against the possible *disturbance of the light to colleagues* ($Med = 3.0$, $IQR = 2.0$), since we saw a major deviation between the two data sets (see Figure 5).

The distribution of both data sets already suggests a strong significance, more precisely the ambient light on the cube being most likely more distracting than the own habits. A one-sided Wilcoxon signed-rank test (*disturbance of own habits to colleagues* < *disturbance of light on cube to colleagues*) showed strong significance ($W = 45.5$, $p = .001$) with a Rank-Biserial Correlation of $r_{rb} = -.697$. Therefore, participants most likely rate the disturbance of their own fidgeting habits lower than the light on the Fidget Cube.

Next, the *disturbance of the light on the Fidget Cube to colleagues* and *oneself* was compared. In contrary to the *disturbance to colleagues*, the *disturbance to oneself* ($Med = 3.0$, $IQR = 2.0$) was not giving such a clear picture.

A Wilcoxon signed-rank test showed no significance ($W = 95.0$, $p = 0.687$). The distribution for *disturbance to oneself* showed high Kurtosis ($\kappa = -1.126$, $\sigma_{\hat{k}} = .821$).

4.3.4 Design. For design, we evaluated the overall *appearance* ($Med = 4.0$, $IQR = 2.0$), *suitability of the luminous ring on the Fidget Cube* ($Med = 4$, $IQR = 1.0$), and *fun factor* ($Med = 4$, $IQR = 0$).

All three variables were compared in a one-sided ($Med_{appearance}$, $Med_{suitability}$, $Med_{fun} > Med_0$) one-sample Wilcoxon signed-rank test against a test value of $Med_0 = 3$ and showed strong significance for all three ($p < .001$).

For further design concept refinement, it was evaluated what colors participants assign to given emotions. This would help in assessing which colors should be used in which interaction scenarios, as the light on the cube for the prototype is currently set to a pulsing blue color.

For anger, all participants chose red, whereas as for fear participants chose blue with 51.6%, for stress, they chose orange with 32.3%, and for excitement — yellow with 35.5%.

4.3.5 Miscellaneous. A few open-ended questions were also asked in the general online questionnaire, to get a full picture of the participants' stance on the Fidget Cube concept. For example, it was asked, how colleagues would react if a participant brought their new fidget toy to work. A qualitative coding analysis showed 5 codes for a positive response, where 53.3% of the participants' answers fell, 2 codes for a neutral response with 23.3% of overall responses, and lastly, 4 codes for negative responses with 23.3% of overall responses. Outstanding responses were from *P24*: *"What do you want with it? Why? I hope, it won't make any sounds."* and *P20*: *"Not convinced and would ask for the necessity."*, while *P2* said: *"If it helps me, I don't care what my colleagues think."*.

5 EXPERIMENTAL DESIGN: EXPLORATORY STUDY

In addition to assessing our concept with an online questionnaire, we conducted an exploratory study on the use of our prototype. The prototype we built, despite the limitations of technical feasibility, is intended to provide results on the actual use of the system. We hoped to gain valuable information for further rounds of iteration in the improvement of the prototype as well as general confirmation on the usefulness and effectiveness of combining these concepts.

5.1 Procedure

Each participant received a package with our prototype, including accessories, a guide with instructions for assembly, consent forms, debriefing information, as well as two questionnaires, one to be filled in before and one after using the prototype (see Figure



Figure 6: Exploratory Study: Sequential Overview of Procedure.

7). After the assembly with the help of the step-by-step instructions and the questionnaire for the pre-survey, a short functionality check followed. The participants were required to use the prototype for at least 30 minutes to a maximum of 8 hours during their working hours. Afterward, they were asked to record their experiences and impressions in the post-survey (see Figure 6). As with the online study, the questions were in the form of a Likert scale (1=*"low/negative"*, 5=*"high/positive"*), but also contained open-ended questions for further qualitative analysis.

During the study, the participants wore a PPG sensor, either on their earlobe or, as shown in Figure 4, on the fingertip. The participants' pulse is measured and evaluated throughout the entire duration of the experiment. Deviations from the resting pulse of an average, athletic and healthy person (60-90 bpm) were evaluated by us as an indicator of a state of arousal. If a participant's pulse rose above the threshold of $bpm \geq 90$, the blue LED on the fidget toy was triggered, changing from bright to dim in a short pulsing animation. The pulsing light is a "Play With Me"-signal for the participants to pick up the cube and use it alongside their main activity.

5.2 Participants

The group of 11 participants consisted of 4 female and 7 male people between 18 and 60 years of age. The volunteers did not receive any kind of remuneration for their participation and were mainly recruited from friends and relatives, as well as from the workplace. The only other selection criterion was the requirement to sit at a desk for several hours a day — at work or studying.

5.3 Results

The prototype of the Fidget Cube with an integrated ambient display of this study may be referred to by *"the system"*, *"the cube"*, *"the fidget toy"* or *"the prototype"*.

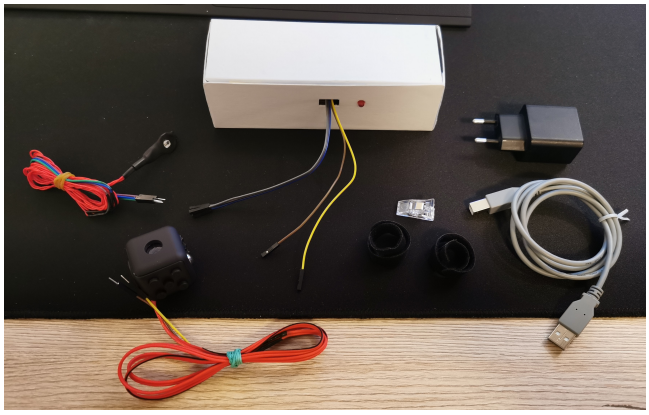


Figure 7: Assembly Kit With All Necessary Parts to Conduct a Contact-Free Study at Home. The Introductory Letter and USB-Stick With All Instruction Were Excluded in This Image.

5.3.1 Target Group Analysis. Similar to the online survey, our participants were mostly in the age range of 25-30 years old (63.3%), while only 18.2% were in the 18-24 age group and only 9.1% each in the 31-35 and 56-60 age groups. At 72.7%, almost three quarters were employed, while the remaining 27.3% were students. A question about the time spent at the desk revealed that 81.8% spend more than 7 hours a day sitting at a desk. With 45.5%, almost half of all participants spend more than 8 hours per day and thus more than what is considered a full working day in Germany.

To map fiddling behavior and experiences with fidget toys, we asked the participants if they had any fidgeting habits which they were aware of. Among 11 participants, we were able to collect 17 habits, which gives us an average of 1.5 fidgeting habits per person. The most frequently mentioned were *"restless leg"* (6x), *"pen clicking"* (4x), *"play with hair or beard"* (3x) and *"nail-biting"* (2x). Despite the self-awareness of fidgeting habits, not all recognized it as a potential source of disturbance for their colleagues. This observation will be addressed in more detail in section 5.3.5.

In order to picture the mood of the group regarding fidget toys, the participants were presented with statements to which they were asked to assign themselves. The statements ranged from *"useless toy"*, *"a distraction from the actual work"*, *"neutral"*, *"good to have, but not necessary"* to *"I can't even start my work without it"*. As in the online study, most participants had a neutral stance (45.5%). Overall, one participant (9%) expressed positive attitude with the statement *"good to have but not necessary"*, whereas 45.5% stated *"a distraction from work"* and 9% agreed with the statement *"useless toy"*. We also asked about any previous experience with fidget toys, whereby two participants stated that they had already had contact with them, once in the form of a stress ball and once as a Rubik's Cube.

To be able to assess the possible effects of our prototype on the ability to regulate emotions, we asked the participants: *"How quickly do you manage to find your balance again after emotional states of arousal?"* As before, short statements were to be assigned, graded in ascending order from short to long recovery time. The distribution among *"Take a breath - move on"* (9.1%), *"After a short coffee break,*

the day can continue" (27.3%), *"After a chat with colleagues I usually feel better"* (54.4%), *"On the way home I leave my workday behind me"* (27.3%) and *"I think about everything until late at night"* (18.2%) shows a normal distribution and supports the representational power of this sample.

5.3.2 Emotion regulation. In order to look at the effects on the ability to regulate emotions, we had the participants record their own general mindfulness in everyday life in the pre-survey. In the post-survey, the corresponding question was repeated under the influence of the prototype and its functional characteristics. For this we used 5-point Likert scales (1=*"low/negative"*, 5=*"high/positive"*). Thus, we were able to get values for *"mindfulness without"* device ($M = 3.909$, $SD = .831$) and values for *"mindfulness with"* device ($M = 3.727$, $SD = .905$) from the post-survey. To perform a paired t-test, we checked the prerequisite values for their normal distribution with a Shapiro-Wilk test that confirmed the normal distribution ($p = .498$). However, the following t-test showed no significance ($p = .64$).

The second important pair of measurements here was the ability to concentrate despite the burden of emotional stress situations. We identified the stress situations *"anger"*, *"nervousness"*, *"anxiety"*, *"stress"* and *"boredom"* as the most relevant markers in everyday office life and collected and evaluated them according to the above described procedure.

In the following paragraph "without" refers to the measurement before the introduction of the prototype and "with" after the introduction of the prototype.

The test results for *"anger"* ($without : M = 2.545$, $SD = 1.572$ and $with : M = 3.182$, $SD = 1.168$) showed a normal distribution of mean differences by the Shapiro-Wilk test p = .158, but no significance in the t-test (p = .208). Furthermore, for *"nervousness"* ($without : M = 2.636$, $SD = .924$ and $with : M = 3.273$, $SD = 1.104$) the Shapiro-Wilk test showed $p = .217$ and thus a normal distribution and with $p = .046$ a significant t-test. To be able to interpret the effect and its significance, we calculated an effect of medium size using Cohen's $d = -0.688$. For *"boredom"* ($without : M = 2.636$, $SD = 1.362$ and $with : M = 3.273$, $SD = 1.104$) the Shapiro-Wilk test showed no significance with $p = .106$, confirming the normal distribution. However, the paired samples t-test did not find any significant differences between the two values ($p = .269$). For the measures of *"anxiety"* ($without : Med = 2.0$, $IQR = 1.0$ and $with : Med = 3.0$, $IQR = 1.5$) and *"stress"* ($with : Med = 4.0$, $IQR = 1.0$ and $with : Med = 4.0$, $IQR = 1.0$), we could not detect a normal distribution (*"anxiety"*: $p = .001$ and *"stress"*: $p =< .001$) and therefore proceeded with a Wilcoxon signed-rank test. While the test for *"stress"* ($p = .275$) failed to demonstrate significance, the test for *"anxiety"* produced a significant with $p = .026$. To further classify this result, we performed a Rank-Biserial Correlation witch showed an effect size of $r_{rb} = -1.0$.

5.3.3 Ability to focus. The values for the ability to concentrate despite exposure to emotional stress situations mentioned in the previous subsection on emotion control can also be attributed to this section and can be reviewed there to avoid repetition.

In addition, there is the general *"ability to concentrate"*. It was measured according to the known scheme ($without : M = 3.909$, $SD = .944$ and $with : M = 3.455$, $SD = 1.036$). A Shapiro-Wilk test

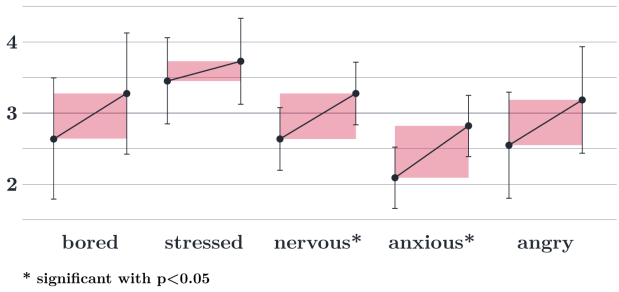


Figure 8: Comparison of the Ability to Work Under Given Emotions.

($p = .035$) provided statistical certainty that the sample we collected could not occur in a normal distribution.

5.3.4 Adequacy of the ambient light as a signal. All variables used in this section followed a 5-point Likert scale (1=*"low/negative"*, 3=*"neutral"*, and 5=*"high/positive"*)) and were evaluated by us with a one-sided Wilcoxon signed-rank tests against a test value of $Med_0 = 3$. To investigate whether the ambient light is a suitable signal, we asked our participants directly: *"How suitable do you find the LED as a signal?"* ($Med = 5.0$, $IQR = 1.0$). We set the alternative hypothesis: $Med_{suitable} > 3$. With $p = .004$, the test showed strong significance.

Other questions for the determination were *"How difficult is it for you to ignore the light on the Fidget cube?"* ($Med = 3.0$, $IQR = 1.0$) and *"Did you feel distracted/disturbed by the light on the Fidget cube?"* ($Med = 2.0$, $IQR = 2.0$). In these cases, the alternative hypothesis was: $Med_{ignorelight}, Med_{distracted} < 3$. No significance was found for either test case ($p = .728$ and $p = .876$).

5.3.5 Acceptance. As mentioned in the target group analysis, with the question *"Do you think colleagues are bothered by your habits?"* we examined the self-assessment of one's own nervous habits, with the degree of one's own distractions by the ambient light (*"Did you feel distracted/disturbed by the light on the fidget cube?"*). Both questions were answered by Likert scales without neutral position for the valid (1=*"Not distracted/disturbed at all"*, 5=*"Very much distracted/ disturbed"*) and evaluated with a one-sides Wilcoxon signed-rank test. *Disturbance of the participants own behavior* ($Med = 2.0$, $IQR = 2.0$) and *disturbance by the light on the cube* ($Med = 2.0$, $IQR = 2.0$) showed no signs of deviation from normality with $p = .363$. The further test procedure could not prove any significance ($p = .335$) in contrast to the results from the online survey.

In open questions, the participants were asked to imagine the reactions of their colleagues. Answers such as from *P1*: *"strange, but can also be very interesting for colleagues"*, *"questioning facial expression"* from *P7*, *"they are curious"* from *P11* or the answer coming from *P9*: *"amused interest"* are a representative sample of the statements. Remarkably, none of them expected a negative reaction.

Later, the participants were also asked to record the actual reactions. Although the vast majority of 81.8% either said they had no colleagues or were currently in home-office, two responses could be classified as *"interested"* and only one as *"amused"*. The predicted

reactions can also be predominantly assigned to these two categories.

5.3.6 Design. Many of the open questions for further suggestions or criticism on the design of the prototype brought up points that are already included in our original concept. We were able to collect statements like those from *P1*: *"Wireless"* or from *P8*: *"The cable to the heart rate monitor is too short (...)"*. Answers regarding the ambient light were e.g. those from *P2*: *"Color can be individualized"*, *"Color change would be nice"* from *P8* or specifically related to the animation *"No pulsating light would be good (...)"* from *P6*.

5.3.7 Miscellaneous. We were also interested in knowing if the participants were able to find a function on the Fidget Cube that met their needs. Nine participants (81.8%) did find a preferred side on the cube, while two people (18.2%) did not. Also in this direction, we asked *"Were you able to replace already existing habits with the help of the cube?"* to which 45.5% answered *"yes"*, but four participants (36.4%) answered *"no"* (the remaining 18.2% said they had none. Equally revealing were the answers to the question of how far the reactions to light on the cube had changed: *"I sometimes just watched the animation of the light in thought without doing anything"* is a statement from *P3*. *P8* stated: *"Yes, at some point I no longer actively noticed the lighting up, but possibly also because I had the cube permanently in my left hand and it was therefore often covered"*, or *"I had to ignore it after a while because otherwise, I would not have been able to do anything other than play with it"* from *P2*.

6 DISCUSSION

The present study was designed to investigate the combination of directional fidgeting and ambient light display visualized biofeedback. We asked the research question of how far the combination of these concepts enables the user to improve his self-perceived performance and overall satisfaction during day-to-day desk work. Our results did not provide us with any evidence of actual increases in concentration or effects on the ability to regulate emotions. Furthermore, we were able to gather impressions about the social implications and acceptance of devices for facilitated fidgeting and compile requirements for the design of ambient light displays in the work context. In the following part, we will critically question our methods, our own assumptions and discuss possible conclusions from the collected data.

6.1 Limitations

At this point, it should be mentioned that many of the following points could not have been achieved otherwise due to the COVID-19 pandemic. Points such as the individual limit for the trigger in the heart rate measurement would have been considered by us under laboratory conditions. However, since our prototype had to pass through the mail from participant to participant, we were forced to limit ourselves to configurations that on average met everyone´s requirements. This also meant that we had to rely on the participants to experiment on their own responsibility and we had to rely on careful execution of the experiment. In addition to the difficulty of recruiting study participants in times of contact restrictions, sharing by mail had imposed additional time hurdles on us, whether it was the mail itself or unreliable participants delaying its delivery. All this led to the fact that we had a proportionally small number of participants, which makes all kinds of statistical verification difficult and has a negative impact on the transferability of the results to reality. We were searching for a long time for a way to expose our participants to various kinds of emotional stress from a distance to make sure that they would actually experience it in their quiet home office environment. In the end we had to rely on subjective impressions to measure the variables. More detailed discussions of the points mentioned will now follow in the corresponding sub-chapters.

6.2 Emotional Self-Regulation

6.2.1 Mindfulness. Although we did not find a significant increase in mindfulness among participants, completing tasks under certain emotions seemed to have an effect. Participants stated to feel more supported by the system when it comes to completing tasks while being in a nervous emotional state. One indicator we wanted to use to show an effect on the ability for emotional control, was mindfulness. Even though it is on everyone's lips due to current trends, the question arises as to whether each of the participants knows how to correctly classify the term. The question about self-perceived mindfulness, both in the pre- and post-surveys, was the most self-attributed value on average. Possible explanations for this could be the consistently positive connotations with it. Due to the broad definition of this abstract term, future evaluations should query more characteristics subsumed under the term than the term itself.

6.2.2 Ability to Focus Under Emotional Stress. Looking at individual participants, the ambient light showed subjectively a strong emotional effect on participants and hinted at some preliminary self-regulation taking place. Of our 5 measured variables for the ability to concentrate under emotional stress states, an effect of medium size was demonstrated for *"nervousness"* and a large effect for *"anxiety"*. Anxiety and nervousness are kindred emotions with many intersections, which explains their relevance compared to the unaffected emotions *"boredom"*, *"anger"*, and *"stress"*. In particular, nervousness has been identified as a reinforcer of fidgeting behavior in previous research [2]. The body's natural response to nervousness through fidgeting provides evidence of the regulatory effect and the fundamental assumption underlying our research.

6.2.3 Can Fiddling Behavior be Replaced? The second group of values for emotion control was the ability to concentrate under emotional stress. The values for nervousness stand out in particular. Contrary to our expectations, we found a negative effect of medium strength here. A possible explanation for this could be the assumed conditions for our experiment. In this study, we aimed to replace existing fidgeting behavior by using the cube. In a query, if the participants were able to replace existing habits at all, it showed that only 50% of the participants were able to do so. A common sign of withdrawal from behavioral addictions is increased nervousness [10]. Literature on the effects of suppressed fidgeting behavior does not currently exist to the best of our knowledge. Further research is needed to determine if this type of habit even intersects with the classification of behavioral addictions.

6.3 Performance and Focus

In our research, we wanted to find out what influence on performance and focus fidget toys, explicitly the concept of a Fidget Cube with an integrated ambient display would have according to participants' assumptions. Neither the exploratory study showed any evidence of an improvement in performance and focus, nor did participants in the online questionnaire assume there might be one. The paired values for focus showed a deviation from our assumed normal distribution in the basic population. Simulations show that the t-tests are robust to the violation of the normal distribution assumption [4]. But even if we had processed the paired values, the result would have been far from significant and are therefore not suitable to contribute to the question of increasing performance which is a topic of controversy in the literature [11, 23]. While preexisting studies have been looking into fidget toys for children, we were — to our knowledge — the first to take fidget toys into the office worker environment. Children are in the stage of rapid cognitive development, while adults are cognitively fully developed [24]. Because of this, kids generally have issues focusing for longer periods and are more easily distracted, while adults are (mostly) not. Therefore, it is possible that fidget toys can show bigger improvements in performance in kids than in adults.

6.4 Acceptance

While fidget toys more and more find their way into big offices, they may still be seen as toys. Bringing fidget toys among office workers supports our assumption. Different variables across both studies suggest a low acceptance of fidget toys and a certain reservation when it comes to improving fidgeting behavior. Fidgeting behavior has always been perceived as disruptive and inappropriate in certain situations [20]. Fidgeting during presentations is seen as a bad habit and "reflects nervousness and insecurity" [2].

6.4.1 It Is Just a Toy. When looking at the Fidget Spinner craze in 2017, it makes sense that fidget toys were banned across many schools. Instead of using Fidget Spinners appropriate to their original purpose, they were essentially used as toys to play with during class. Incidents like these add up to the "bad connotation" [20] of fidget toys, which result in lower acceptance, especially among adults. Both the online questionnaire and the questionnaire for the prototype study revealed some prejudices against fidget toys. Although the large majority of the participants stated that they had not had any previous contact with such objects, such reservations and the associated "self-fulfilling prophecy" [19] may have influenced the results. We suspect that the word "toy" may have triggered stereotype thinking. In further studies, this consideration could be validated, by framing the cube in one of the groups as a medical training device for fine motor skills.

6.4.2 Issues of Self-Assessment Regarding Own Behavior. Despite the prevalence of nervous habits, the majority of participants could not imagine bothering their colleagues with them. This may be consistent with Kriescher's [11] observations and the distinction of fidgeting behavior into facilitated and natural fidgeting. Many of the behaviors mentioned can be attributed to natural fidgeting, which is done without tools and thus often unconsciously. Our question about it may have drawn this behavior into consciousness, but not the effects on the environment. In contrast to this is the assumption of many that the ambient light display will not distract them but colleagues. Here, psychological mechanisms that lead to problems in estimating self-efficacy may have distorted the test results.

6.4.3 Stumbling Block: Personal Relationships. Another hurdle is the recruitment of our participants in the work and family environment, a presumption that also supports the lower acceptance in the prototype study compared to the online questionnaire that was carried out more widely. Given this participant selection process, it is not excluded that response bias may have influenced the results, although we found no clear evidence of this. Perhaps the simplest solution to this would be to conduct the experiment in an official laboratory, which would give it a more professional framing.

6.4.4 Secondary Functions. Although many of the participants seem to be biased towards the fidget toy, the actual reactions from colleagues were almost entirely one of curious interest. Thus, beyond its intended use, such an object can have valuable social implications. Even if only of secondary importance, its use with authorities as a conversation opener would be a possibility or to appear more approachable and human.

6.5 Design

6.5.1 Ambient Light as Suitable Signal. Including an ambient display in our concept proved to be a challenge. When working with ambient displays — context is key. Mankoff et. al. suggest heuristics for ambient display evaluation, under which falls the "match between design of ambient display and environment[...]" [15]. We still lack a definite settlement in terms of the suitability of the ambient display presented in our concept. Because of the current home office situation, the majority of our participants cannot make any well-founded statements about the question of whether colleagues actually feel distracted by the light signal. The effect on the participants was ambivalent. Many (5/11 participants) stated that they felt disturbed by the light. The light of the cube is appealing to participants as it is, but it is not clear whether the light was distracting in the actual user scenario or not. Furthermore, it is unclear whether the answers refer to the animation, the color, or the frequency of the light. In response to the direct question of whether the light signal is perceived as appropriate, we received convincingly positive feedback. Either way, more user tests with a higher sample size and diverse design variants have to be conducted, in order to achieve a representative assertion.

6.5.2 Colors and Animations. The blue LED in the Fidget Cube was chosen because of the calming effect of the blue color. As defined in the related work section on ambient displays (see section 2.2), the light was used here primarily for its signaling effect. Our own surveys in the study, in which only negative emotions were to be assigned to colors, revealed a broad association of colors with emotions, with the exception of a few culturally learned associations (e.g., red = anger). Further research with colors, lighting patterns, and interaction methods is necessary, to observe different effects on mood regulation. However, our research also suggests that color-coding different emotions fluctuated strongly between individuals. Instead, biosignals should be directly reflected (heightened pulse,

increase in sweat production, lower skin temperature) and colors should be assigned by the individual user. In this way, the user experience of the product could be enhanced with simple methods. The use of animation should be treated with caution. Overly frantic and agitated animations have the potential to undermine the idea of the unobtrusiveness of an ambient display. However, there are undeniable advantages in using animation to visualize progress in future studies.

6.5.3 Design Considerations for the Fidget Device. Since the requirements for fidget devices are as individual as the people themselves, we have chosen the Fidget Cube, a fidget toy that is characterized by its versatility. Despite the variety of interaction possibilities, two of our participants stated that they had not found a function on the cube that matched their preferences. For further studies, it should be considered whether data from participants whose fiddling needs cannot be satisfied by the selected Toy, should be treated differently because they do not match the target group of the final application. In general, the choice of the Fidget Cube turns out to be the right one. An overwhelming majority found the design appealing, whereby it must be noted that we worked with the full black version, although it is already available in all kinds of colors and color combinations.

6.6 Biofeedback

The evaluation of the open-ended questions suggests that a general HR range as we have defined it to detect arousal states is not practicable. Participants reported being forced to ignore the light signal because their normal level of arousal at work was so high that they could not do anything else. We strongly recommend that future study participants take into account individual characteristics of the pulse such as gender, endurance level, and body stature. Another assumption included in the concept was confirmed by feedback from participants about the type of pulse measurement. For everyday work routines, only completely contact-less or unobtrusive sensors come into consideration. In our concept, we propose measurements via smartwatches. Although current models do not yet have sensors such as skin resistance meters, which are intended for the interpretation of emotional states, a growing industry is currently developing smartwatches and their sensor technology for use in high-performance sports. Other possibilities include measurement via webcams [17], but their accuracy does not reach the level of body sensors. Another interesting approach to the issue is the integration of sensors into existing everyday objects, such as chairs [25].

7 CONCLUSION

In our research, we wanted to find the effects of an Fidget Cube with an integrated ambient display on performance, focus and self-regulation of emotions. While the Fidget Cube serves as a medium to channel natural fidgeting behavior when in an emotional distressed state, the ambient light is the primary source for the user to communicate their emotional state and a way to rise self-awareness and therefore induce preliminary self-regulation. To gain insights on the concept, we conducted an online questionnaire ($n = 31$) and tested the interaction and suitability of the ambient light with a prototype ($n = 11$). Our research showed that participants worked longer than 8 hours (45.5% in exploratory study, 29% in online questionnaire) and have trouble to leave emotional distress in the workplace behind (18,2% for exploratory study, 31,3% in online questionnaire), which supports our initial assumptions about the challenges of an office worker that fueled this study. With our research, we paved the way in researching fidgeting behavior in adults — more specifically office workers — and explored the integration of an ambient display with the purpose to provide biofeedback for stress management. We especially see great potential in the use of ambient displays in everyday items in the office environment. Even if the Fidget Cube does not end up being as effective in adults as first anticipated, using the item as a carrier object to introduce more biofeedback in the lives of office workers, could still provide self-regulatory benefits.

REFERENCES

[1] Hussein Al Osman, Mohamad Eid, and Abdulmotaleb El Saddik. 2014. U-biofeedback: a multimedia-based reference model for ubiquitous biofeedback systems. *Multimedia Tools and Applications* 72, 3 (2014), 3143–3168. https://doi.org/10.1007/s11042-013-1590-x

[2] Scott A Barnard. 2009. *The" Stop-It" Anti-fidgeting Device.* Florida Atlantic University.

[3] F. Bergmann. 2019. *New Work New Culture: Work We Want And A Culture That Strengthens Us.* John Hunt Publishing. https://books.google.de/books?id=FNeaDwAAQBAJ

[4] Jürgen Bortz. 2005. *Statistik für Human- und Sozialwissenschaftler* (6 ed.). Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/b137571

[5] Manfred Faber and Hergen Riedel. 2014. *Trendthema Work-Life-Balance: Nicht mehr nur die Karriere zählt.* Springer Fachmedien Wiesbaden, Wiesbaden, 29–36. https://doi.org/10.1007/978-3-658-07169-1_8

[6] Peter Kaiser. 2007. Physiological response to color: A critical review. *Color Research & Application* 9 (03 2007), 29 – 36. https://doi.org/10.1002/col.5080090106

[7] Ashish Kapoor and Rosalind W. Picard. 2005. Multimodal Affect Recognition in Learning Environments. In *Proceedings of the 13th Annual ACM International Conference on Multimedia* (Hilton, Singapore) *(MULTIMEDIA '05).* Association for Computing Machinery, New York, NY, USA, 677–682. https://doi.org/10.1145/1101149.1101300

[8] Michael Karlesky and Katherine Isbister. 2016. Understanding Fidget Widgets: Exploring the Design Space of Embodied Self-Regulation. *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, Article 38 (2016), 10 pages. https://doi.org/10.1145/2971485.2971557

[9] Norbert Kersten, Maren Formazin, and Grit Müller. 2020. Burnout und psychosoziale Arbeitsbedingungen in Berufsgruppen mit hohen kognitiven Anforderungen. *Zentralblatt für Arbeitsmedizin, Arbeitsschutz und Ergonomie* 71, 1 (oct 2020), 8–18. https://doi.org/10.1007/s40664-020-00409-3

[10] D. Gerhard Bühringer Klaus Wanke. 1991. *Grundstörungen der Sucht.* Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-642-95644-7

[11] Stephanie LeAndra Kriescher. 2020. *The Effects of Fidgets on Attention and Learning of CollegeStudents.* Text. University of Northern Colorado.

[12] R. Gregory Lande, Lisa Banks Williams, Jennifer L. Francis, Cynthia Gragnani, and Melanie L. Morin. 2010. Efficacy of biofeedback for post-traumatic stress disorder. *Complementary therapies in medicine* 18 (Dec 2010), 256–9. Issue 6.

[13] Andreas Lehner. 2006. *Integrierte Objekte als periphere Informationsträger; Entwurf einer Taxonomie für Ambient Displays.* Ph.D. Dissertation.

[14] Rong-Hao Liang, Bin Yu, Mengru Xue, Jun Hu, and Loe M. G. Feijs. 2018. BioFidget: Biofeedback for Respiration Training Using an Augmented Fidget Spinner. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18).* Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3174187

[15] Jennifer Mankoff, Anind K. Dey, Gary Hsieh, Julie Kientz, Scott Lederer, and Morgan Ames. 2003. Heuristic Evaluation of Ambient Displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Ft. Lauderdale, Florida, USA) *(CHI '03).* Association for Computing Machinery, New York, NY, USA, 169–176. https://doi.org/10.1145/642611.642642

[16] Vanita Irene Matta. 2015. Führen selbstgesteuerte Arbeitszeiten zu einer Ausweitung der Arbeitsstunden? Eine Längsschnittanalyse auf der Basis des Sozio-oekonomischen Panels. *Zeitschrift für Soziologie* 44, 4 (2015), 253–271.

[17] Daniel McDuff, Javier Hernandez, Sarah Gontarek, and Rosalind Picard. 2016. COGCAM: Contact-free Measurement of Cognitive Stress During Computer Tasks with a Digital Camera. 4000–4004. https://doi.org/10.1145/2858036.2858247

[18] Matthew McLachlan and Mark McLachlan. 2016. Fidget Cube: A Vinyl Desk Toy. Kickstarter. https://www.kickstarter.com/projects/antsylabs/fidget-cube-a-

vinyl-desk-toy

[19] Robert K. Merton. 1948. The Self-Fulfilling Prophecy. *The Antioch Review* 8, 2 (1948), 193–210. http://www.jstor.org/stable/4609267

[20] Jessica Mize. 2018. Rethinking Fidgeting: Not Rude, But Productive and Healthy. *ENGAGE: Dialogue to Empower Social Change* (Oct. 2018). https://www.claremontlincoln.edu/engage/ethical-leadership/rethinking-fidgeting-productive-healthy/

[21] Robert Reiner. 2008. Integrating a portable biofeedback device into clinical practice for patients with anxiety disorders: results of a pilot study. *Applied psychophysiology and biofeedback* 33 (Mar 2008), 55–61. Issue 1.

[22] Mary J. Ross, Paul Guthrie, and Justin-Claude Dumont. 2013. The impact of modulated, colored light on the autonomic nervous system. *Advances in mind-body medicine* 27 (Fall 2013), 7–16. Issue 4.

[23] Sheryl Stalvey and Heather Brasell. 2006. Using Stress Balls to Focus the Attention of Sixth-Grade Learners. *The Journal of at-risk issues, 2006, Vol.12(2), p.7* 12, 2 (2006), 7.

[24] Ow Li Xuan Viola, Zheng Shiyang, and Priscilla Tan Yi Jia. 2014. Differences between child and adult learning: Cognitive abilities. https://blogs.ntu.edu.sg/hg2014-2014-8/?page_id=34

[25] Marian Walter, Benjamin Eilebrecht, Tobias Wartzek, and Steffen Leonhardt. 2011. The smart car seat: Personalized monitoring of vital signs in automotive applications. *Personal and Ubiquitous Computing* 15 (10 2011), 707–715. https://doi.org/10.1007/s00779-010-0350-4

[26] Amanda L. Wheat and Kevin T. Larkin. 2010. Biofeedback of heart rate variability and related physiology: a critical review. *Applied psychophysiology and biofeedback* 35 (Sep 2010), 229–42. Issue 3.

[27] Anne Wöhrmann. 2016. *Arbeitszeitreport Deutschland 2016.* Verlag Kettler GmbH, Bönen.

[28] Bin Yu, Jun Hu, Mathias Funk, and Loe Feijs. 2018. DeLight: biofeedback through ambient light for stress intervention and relaxation assistance. *Personal and Ubiquitous Computing* 22, 4 (2018), 787–805. https://doi.org/10.1007/s00779-018-1141-6

[29] S.S. Zentall. 2006. *ADHD and Education: Foundations, Characteristics, Methods, and Collaboration.* Pearson/Merrill Prentice Hall. https://books.google.de/books?id=-sxKAAAAYAAJ