EVALUATING THE IMPACT OF MULTIPLE METHODS ON MOTOR MEMORY TRAINING AND ABSENT-MINDEDNESS

A Thesis

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Masters of Science

By

Haoyu Zhang

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BIOGRAPHICAL SKETCH

Haoyu Zhang obtained a Master of Science degree in Design + Environmental Analysis, with a concentration in Human Factors & Ergonomics, from Cornell. He earned his Bachelor of Arts degree in Industrial Design at the University of Michigan, Ann Arbor. He aims to become a designer and utilizes his knowledge and experience from multiple fields to solve problems for people and benefit society.

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ABSTRACT

Absent-mindedness is a diagnosable mental health condition which individuals experience lapses of attention. Absent-mindedness has many causes and could be experienced by a wide range of populations. Experiencing absent-mindedness is inconvenient and disturbing, and it could lead to forgetful behaviors, such as forgetting important items like wallets and keys. Experiment 1 of the present study examined whether a new type of "smart tray" for storing small personal items could mitigate the effect of absent-mindedness through the implementation of visual feedback and development of user's motor memory. In experiment 2, we added haptic feedback and acoustic feedback to the smart tray we used in experiment 1 to establish a feedback ecosystem. The motor memory training outcome and treatment effect to absent-mindedness of the three types of trays (visual feedback *vs.* no feedback *vs.* multiple feedbacks) were evaluated and compared to each other. Results show that the visual feedback group achieved better motor memory performance, was less affected by absent-mindedness, and had better user experience than the no feedback group. The feedback ecosystem group achieved the best motor memory performance and was even less affected by absent-mindedness than the visual feedback group. However, they had the worst user experience among the three groups. The findings suggest that implementing visual feedback and multiple feedbacks to train people's motor memory is effective to mitigate or prevent absent-mindedness, but it is important to evaluate both the positive and negative impacts of each feedback method and to find the correct combination of feedback methods to optimize the product's effectiveness.

Introduction

Absent-mindedness is a diagnosable mental health condition which individuals experience lapses of conscious awareness and impairs their goal-directed behaviors (Jang & Seo, 2017; Reason & Lucas, 1984). Experiencing absent-mindedness can be inconvenient and disturbing. The consequences of absent-mindedness may vary from simple problems like forgetting one's keys to significant and dangerous incidents such as traffic accidents (Donmez et al., 2007; Robertson et al., 1997). For people who experienced high levels of absent-mindedness, they could be caught by inattentive and forgetful behaviors (Cheyne et al., 2006) and difficulties with memorization (Squire & Dede, 2015; Craik & Tulving, 1975). Those consequences made absent-mindedness a problem that was hard to ignore.

What Causes Absent-mindedness and Who Experiences It

Previous studies have attributed the phenomenon of absent-mindedness to a wide range of causes, ranging from physical causes, such as previous brain damage (Jang & Seo, 2017) and the effects of cancer (Scott et al., 2020), to environmental distractions (Donmez et al., 2007). The incidence of absent-mindedness was found to be closely associated with people's attention levels (Cheyne et al., 2006). Other studies also found a higher chance of experiencing absent-mindedness while the participant was performing other tasks, which was common in people's daily life. Incidence of experiencing absent-mindedness was found to be positively related to the complexity of the tasks being performed (Buckley et al., 2016), the duration of those tasks (Hlas et al., 2017), and negatively related with the physical activity levels while completing tasks (Hüttermann & Memmert, 2012).

Previous studies also pointed out many people could get caught by absent-mindedness. Some researchers found absent-mindedness was often associated with brain disorders such as Autism Spectrum Disorder and Parkinson's Disease (Vaillancourt et al., 2001; Badarny et al., 2014; Neely et al., 2016). In addition, other studies indicated that absent-mindedness could also be experienced by populations of widely different ages and health statuses.

Surprisingly, young, mentally healthy human was also vulnerable to absent-mindedness. Some researchers purposefully recruited young, healthy participants for absent-mindedness-related experiments,

and they found a high proportion of participants showed symptoms of absent-mindedness during their experiments. For example, Simons and Chabris (1999) recruited healthy college students and found that 46% of the participants displayed signs of absent-mindedness while watching the "Gorilla Video" designed for this experiment. More than half of the participants failed to notice an unexpected gorilla appearing on the screen of a basketball video in which they were asked to count the number of basketball passes. Similarly, Hüttermann and Memmert (2012) found that 80% of healthy participants displayed symptoms of inattentional blindness while performing an identifying task, and Koivisto and colleagues (2004) found that 83% of healthy participants failed to detect an unexpected object when it appeared in their environment. The results of those experiments reflected that healthy participants were vulnerable to absent-mindedness while their attention was shifted, either by the environment surrounded them or other people or tasks. Considering the complex causes for experiencing absent-mindedness and its large number of potential victims, we believed it was crucial to find a general solution to mitigate or prevent absent-mindedness for the benefit of many people.

Current Solutions to Absent-mindedness

Due to the widespread nature of absent-mindedness and the inability to identify a clear, singular cause for the phenomenon, researchers in this area have focused on generalized treatments to prevent or mitigate its effects. The two major approaches are (a) the use of visual feedback and (b) enhancing motor memory.

Previous studies had proved that absent-mindedness was linked with people's vision. For example, in their famous "Gorilla Video" experiment, Simons and Chabris (1999) found that conscious attention influenced the encoding and retaining processes of the human brain, especially when information was collected through visual input. This study demonstrated that occurrences of absent-mindedness were linked to a condition of observational and memory-encoding lapse, known as "inattentional blindness."

Many subsequent studies attempted to find ways to prevent or mitigate the effects of this inattentional blindness caused by episodes of absent-mindedness. The results of these studies eventually

gravitated toward support for the effectiveness of visual feedback and enhanced muscle memory. By manipulating the color of stimulus objects, Koivisto and colleagues (2004) found that they could help participants to achieve higher success rates in noticing the appearance of unexpected objects (in other words, reducing inattentional blindness). Shafter and colleagues (2019) expanded this finding by using EEG to track participants' neurological responses while performing tasks. The study indicated that human brains were engaged in a greater extent of information-processing when visual feedback (such as color differences) was provided as part of the tasks. The results of those studies proved that implementing visual feedback was an effective treatment for absent-mindedness.

Other studies investigated the absent-mindedness problem from the perspective of developing people's motor memory. Motor memory training is regarded as reducing the effects of absent-mindedness in two ways: by increasing people's attention level and by reinforcing their memorization processes. In an early study, Craik and Tulving (1975) concluded that attention and memory performance were highly dependent on the extent of an individual's motor interaction with an object or environment. The same positive relationship between motor skills and attentiveness was shown more definitively by Kee and Liu (2011), who evaluated the interaction between attention states and a manual task (turning a gyroscope). Thomas (2013) found that foreign speakers spontaneously applied the motor activity of kusho (an "air writing" technique that involves tracing out the patterns of Sino-Japanese characters), while learning Japanese vocabularies. The frequency of applying kusho was positively associated with the difficulty level of those vocabularies. In another language-related experiment, Ohki (2004) found participants who received visual and audio feedback acquired stronger motor memory. The findings of those studies proved that developing motor memory was an effective way to treat absent-mindedness.

Previous studies had proved that both implementing visual feedback and developing motor memory were two effective ways to mitigate or prevent the occurrence of absent-mindedness. In addition, several studies have provided evidence that visual feedback can contribute to the development of motor memory. For instance, Badarny and colleagues (2014) implemented visual feedback through VR devices to help patients with Parkinson's Disease to improve their walking performance. Patients who received

visual feedback were found to achieve longer stride length and faster walking speeds than the group who received no visual feedback. Similar studies on muscle control obtained commensurate findings regarding the value of visual feedback during physical therapy sessions (Neely et al., 2016; Vaillancourt et al., 2001). We believed the approach of implementing visual feedback to treat absent-mindedness, and the approach of developing motor memory to treat absent-mindedness, may actually be interrelated. Thus, our study aims to further investigate the integrated relationship between visual feedback, motor memory, and absent-mindedness, and proposes a solution based on this method.

Existing Products Targeting Absent-mindedness

Many researchers have found that memory aids can significantly improve the quality of daily life for individuals who experience high levels of absent-mindedness (Sohlberg et al., 2007; Hildebrandt, 2019). These aids can range from simple written notes to more complex electronic devices, with consumer demand for electronic memory aids experiencing a high level of growth in recent decades (Cohen-Mansfield et al., 2005). There are few studies, however, that have explored the efficacy of electronic memory aid devices. Some of the products that have been previously marketed in this area were criticized for their narrow focus, awkward user experiences, and low frequency of use (Cohen-Mansfield et al., 2005; Sohlberg et al., 2007; Hildebrandt, 2019).

One of the most popular categories of memory-aid products is those that aim to solve the problem of losing important items. Most of these products focus on allowing the user to track important items, such as keys or wallets, after they have already lost them. For instance, Apple's AirTags, and any other RFID products, require users to attach the products to their items in advance. When those items are missing, limited information through a two-dimensional map is available to users to track the lost items. Some users also complained that the tracking function of those products would be disabled or lose its precision when the attached items were moving or their smartphones' signal was poor. This approach,

however, has some limitations because it does not address the origin of the problem, which occurs when the user first has an experience of absent-mindedness and leaves an item behind.

Purpose of the Current Study

The current study was carried out to evaluate a new type of electronic memory aid that focuses on implementing visual feedback to help users keep track of important physical items. The concept behind this design is that, based on the prior literature, the addition of visual feedback may improve motor memory performance over time and mitigate episodes of inattentiveness that lead to lost everyday objects such as keys, wallets, and glasses. Thus, the device addresses the moment in which the items are lost, rather than simply helping to locate them after they have become lost.

The design was based on the understanding that absent-mindedness leads to everyday objects becoming lost because individuals place them in random locations and then have a hard time retrieving them. The solution took the form of an "interactive tray" that would be located near the entrance to a home, which would provide visual feedback depending on whether or not specific objects were placed into the tray when the user came through the door. The visual feedback was understood as a way to give an immediate prompt to help avoid forgetful behavior, but also with the hope that over time this feedback would help to promote a habitual muscular action of placing items into the tray, instead of leaving them at random other locations. While numerous other commercially available trays exist for storing keys and wallets, these existing products do not have clearly designated spots for each item and do not incorporate visual feedback functions.

We conducted two experiments related to the success of this product, each of which will be discussed in turn. Experiment 1 evaluated the effect that using the tray with visual feedback had on motor memory performance and incidences of lost items. After conducting this experiment, we decided to add vibrator and speaker modules to the tray, providing audio and tactile feedback as well as visual. Experiment 2 evaluated the success of these combined feedback formats compared to visual feedback alone. Both of the experiments used the same metrics to evaluate the tray's success at preventing lost items for users with a history of absent-mindedness.

Experiment 1: Methods

A total of 30 participants were recruited for Experiment 1, using a convenience sampling method. Participants were recruited through emails and WeChat messages. Due to previous findings that absent-mindedness can be experienced by a wide range of otherwise healthy individuals (Hüttermann & Memmert, 2012; Simons & Chabris, 1999), a formal diagnosis of absent-mindedness was not required for inclusion, so there were no specific demographic or medical requirements for participating in the study, other than being over the age of 18 and able to give consent. Fifteen of the participants were randomly selected to use the "smart tray" with visual feedback in their everyday lives (Experiment Group), while the other fifteen used a physically identical "dumb tray" without any visual feedback (Control Group).

Product

The tray was based on a modular design (Spacey, 2016), which allowed users to customize it by adding dividers to create compartments for specific small personal items (keys, phone, wallet, glasses, etc.) (Figures 1 and 2). Each tray used in the experiment was fabricated using a 3D printer, and the "smart" versions of the tray integrated Arduino sensors and LED lights. Subtle breathing light would be delivered when the pressure sensors detected if an item was present at the designated location in the tray; rapid blinking light would be delivered when the item was missing. The goal of this approach was to train the user's motor memory to store their items at a specific place when they entered their residence based on two types of visual feedback. The "dumb trays" used by the control group did not contain sensors or LED strips, but were otherwise identical to the smart trays in terms of their materials, appearance, size, and customizable compartments.

Figure 1

Design of the Smart Tray: (a) Modular Design Allows the User to Customize the Tray with Different Dividers, and (b) Using Dividers to Make Appropriate Spaces to Store Different Items

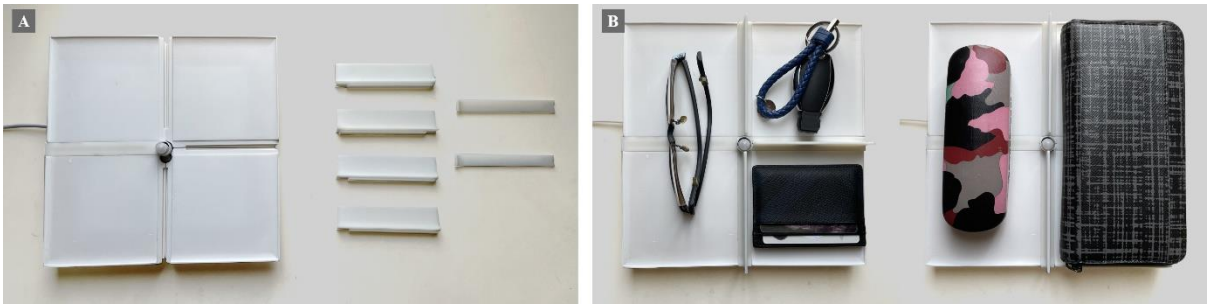


Figure 2

Implementation of Visual Feedback: (a) The Smart Tray with LEDs Off (at Left) Vs. Activated (at Right), and (b) The Smart Tray (at Left) Vs. a Normal Tray (at Right)

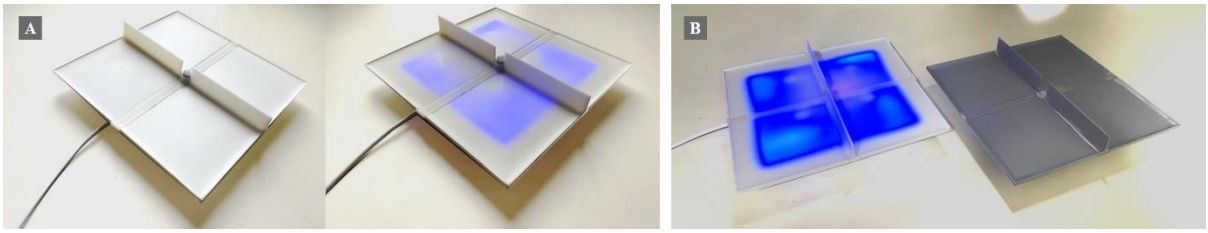


Figure 3

A User Interacts with the Smart Tray

Procedure

Due to the challenges created by the COVID-19 pandemic, this experiment was designed as an unmoderated, seven-day user-testing approach. The study procedures were reviewed by the IRB **[deleted for the purpose of blind review]**, which determined that the research would pose no risks to human objects. At the beginning of the study each participant filled out an online consent form and a pre-experiment questionnaire. Individuals who agreed to participate in the study received a delivery box containing either a "smart" or "dumb" tray (depending on their randomly assigned experimental group) along with its divider attachments, and instructions for customizing the tray by using the dividers to create separate sections for each personal item that they wanted to store on the tray. They were asked to place the tray near the entrance of their homes for regular use. At the end of the seven-day period, the participants were asked to mail the trays back to the researchers, and to fill out an online post-experiment

questionnaire. When the returned tray and completed questionnaire were received by the researchers, each participant was compensated with 65 Chinese Yuan (about $10 U.S. dollars) through the Alipay platform.

Metrics

To measure absent-mindedness, most prior studies have used either a quantitative method or else a mixed-methods approach encompassing both quantitative and qualitative data. Likert-scale questionnaires were commonly used to obtain quantitative data regarding the prevalence of absent-mindedness, though this approach has the limitation of being a self-reported evaluation. Some researchers have used more objective measurements, including task performance scores, observed errors or missed stimuli, and physiological data. In the current study we used six measurement instruments, all of which were self-reported, along with a demographic questionnaire.

Prior to the experiment, the participants provided demographic information (age, sex, education level, perceived level of absent-mindedness, etc.) and completed four measurement instruments focused on variables that could have a moderating effect on the main relationship between visual feedback and absent-mindedness. Those moderator variables were participants' mental health condition as measured by the Positive Mental Health Scale (PMH-Scale) (Lukat et al., 2016), their living environment quality as measured by the Residential Environmental Satisfaction Scale (RESS) (Adriaanse, 2007), their attentional capacity as measured by the Attention-Related Cognitive Errors Scale (ARCES) (Carriere et al., 2008), and their familiarity with "smart" interactive devices as measured by the Internet of Things Questionnaire (IoT) (Cannizzaro et al., 2020). After completing the seven-day experiment, the participants also filled out two questionnaires designed by the current researchers, which measured task performance levels as well as subjective perceptions of the product. These instruments were named the Product Feedback Questionnaire (adapted from Brown & Ryan, 2003, and Carriere et al., 2008) and the User Experience Scale (adapted from McAuley et al., 1989). All of the instruments used a Likert-scale format.

Positive Mental Health Scale (PMH-Scale). Lukat and colleagues (2016) developed the PMH-Scale as a brief, unidimensional instrument to measure positive mental health levels. This approach is based on the view that the presence of positive mental health is different from the absence of mental

disorders. Previous studies have found that participants with no diagnosed mental disorders still have a relatively high incidence of absent-mindedness while performing required tasks during experiments (Cheyne et al., 2006; Buckley et al., 2016; Hlas et al.,2017; Simons & Chabris, 1999; Hüttermann & Memmert 2012). The PMH-Scale was included in the current research to determine if there might be a moderating effect of positive mental health levels.

Residential Environmental Satisfaction Scale (RESS). Adriaanse (2007) developed the RESS to measure participants' satisfaction with their living environments. It includes questions that address both indoor living circumstances and the broader context of relations with neighbors and the local external environment. Previous studies have indicated that the occurrence of absent-mindedness was highly dependent on the surrounding environment (Simons & Chabris, 1999; Adam & Vogel, 2018). We included the RESS to evaluate if the participants' perception of their living conditions might have a moderating effect on the relationship between visual feedback and absent-mindedness.

Attention-Related Cognitive Errors Scale (ARCES). Developed by Carriere and colleagues (2008), ARCES is a Likert-scale questionnaire that evaluates the prevalence of attentional failures. Previous researches have established a strong link between absent-mindedness and attention lapses (Buckley et al., 2016; Hlas et al., 2017; Koivisto et al. 2004; Badarny et al., 2014). Essentially, the perspective in this research is that a lack of attentiveness tends to make people susceptible to distractions, which then contributes to the larger phenomenon known as absent-mindedness. The purpose of including the ARCES in the current research was to evaluate a potential moderating effect of attentiveness levels on the relationship between visual feedback and absent-mindedness.

Internet of Things Questionnaire (IoT). Adapted from Cannizzaro and colleagues' (2020) scale, this questionnaire measured participants' familiarities, adoption, and acceptance of interactive or "smart" home devices. Some individuals may be uncomfortable with such devices due to lack of experience and understanding, whereas others may hold negative views toward such technology due to concerns about tracking, hacking, or the use of personal information. The IoT instrument evaluated both of these considerations. The purpose of including the IoT questionnaire in the current study was to evaluate if a

lack of comfort with this type of technology might have a moderating effect on the value of the smart-tray product for reducing absent-mindedness.

Product Feedback Questionnaire. The current researchers developed this questionnaire based on two previous studies (Brown & Ryan, 2003; Carriere et al., 2008) that investigated the relationship between motor memory and absent-mindedness. The goal of this questionnaire was to track and measure the details of the user's experience with the products, the motor memory training effect, and the impact on absent-mindedness.

User Experience Scale. This scale was adapted from a study conducted by McAuley and colleagues (1989) to obtain user feedback about a product. In the current study the user experience scale was tailored to collect general quantitative user feedback related to the tray product (the questions were the same for both the "smart tray" and the "dumb tray" participant groups). The responses to this questionnaire were intended primarily to inform future product development efforts.

Hypotheses and Data Analysis

Experiment 1 was intended to investigate the effect of visual feedback via the "smart tray" (independent variable) on motor memory training outcomes and on the incidence of absent-mindedness (dependent variables). The following hypotheses were tested:

Hypothesis 1. Participants who used "smart" trays with visual feedback will have better motor memory performance compared to participants who used trays without visual feedback.

Hypothesis 2. Participants who received visual feedback and had better motor memory performance will be less affected by absent-mindedness compared to participants who received no visual feedback and had poorer motor memory performance.

Hypothesis 3. Participants who used trays with visual feedback will report a better user experience compared to participants who used normal trays.

Hypothesis 4. Participants' positive mental health, residential environment satisfaction, and reported comfort with smart devices will have positive correlations with motor memory training result and negative correlations with absent-mindedness.

Hypothesis 5. Participants' reported level of attention-related errors will have negative correlations with motor memory training result and positive correlations with absent-mindedness.

To conduct the data analysis, the scores of participants in each of the two experimental groups ("smart tray" and "normal tray") were averaged on each of the questionnaire instruments. We then conducted ANOVA tests with α level set to 0.05.

Hypothesis 1 was tested by running an ANOVA test to compare the motor memory training outcome between two groups. Items 10–12 and item 18 of the Product Feedback Questionnaire measured participants' subjective opinions on the motor memory training outcomes. Items 13–17 measured the effect of implementing visual feedback on motor memory training. Some questions varied depend on the presence of the visual feedback, for instance, item 13 of the Product Feedback Questionnaire answered by the experiment group stated "The visual feedback provided by the LED lights reminds me to interact with the tray", while item 13 answered by the control group stated "I can remember to put items back to the assigned sections of the tray". Some of the items mentioned above were reversely coded to ensure a positive relationship between the score and motor memory training outcomes and visual feedback's effect on motor memory.

Hypothesis 2 was tested by running an ANOVA test to compare the absent-mindedness related experience between two groups. Item 1–6 of the Product Feedback Questionnaire measured participants' experiences of absent-mindedness during the experiment by asking questions like "I usually forget to pick up daily items that I need (e.g., door keys, car keys, wallet, watch) when leaving the house". All the six items were reversely coded, and participants who experienced less absent-mindedness would receive higher score for item 1-6. Items 7–9 and item 20 measured the effect of motor memory training on absent-mindedness. For example, "Using the tray helps me to remember what daily items I need to carry with". Participants received higher score for item 7-9 represents stronger treatment effect of motor memory on absent-mindedness.

Hypothesis 3 was tested by running an ANOVA test to compare the general user experience between two groups. The User Experience Scale asked questions such as "I have enjoyed the

experience" and "I want to purchase the product" to measure people's user experience and satisfaction rate with the tray products they used during the experiment period. Higher score represents better user experience.

Hypothesis 4 and Hypothesis 5 was tested by running a linear regression model to test if participants' positive mental health condition, residential environment satisfaction, reported level of attention-related errors, and reported comfort with smart devices has moderation effect on the relationship between visual feedback, motor memory, and absent-mindedness.

Experiment 1: Results

All 30 of the recruited participants successfully completed the survey instruments and returned their assigned trays to the researchers at the end of the seven-day experiment. The demographic data collected from these participants is shown in Table 1. The majority of the participants were in the 18–30 age range (n=17), lived together with family members in a residence that they owned (n=16), and reported having recent experiences of absent-mindedness (n=21).

Table 2 describes the participants' scores on the four pre-experiment questionnaires related to potential moderating variables. The scores on these tests conformed very closely to average (between 3.1 and 3.4 on a 5-point Likert-scale), and they displayed little standard deviation (less than 0.75).

Table 3 describes the participants' scores on the two post-experiment questionnaires. These scores are broken down according to the response items that were used to test each hypothesis. The detailed results of the ANOVAs that were run for each hypothesis are shown in Figure 4.

In regard to Hypothesis 1 (participants who used "smart" trays with visual feedback will have better motor memory performance compared to participants who used trays without visual feedback), the experiment group was found to achieve a significantly better reported motor training outcome compared to the control group (Product Feedback Questionnaire items 10–12 and 18, $F(1, 28) = 24.7$, $p < 0.001$). Furthermore, the participants in the experiment group with visual feedback reported significantly better motor memory development, compared to the control group (Product Feedback Questionnaire items 13–17, $F(1, 28) = 57.88$, $p < 0.001$). Thus, Hypothesis 1 was strongly supported.

In regard to Hypothesis 2 (participants who received visual feedback and had better motor memory performance will be less affected by absent-mindedness compared to participants who received no visual feedback and had poorer motor memory performance.), the experiment group was found to experience significantly less absent-mindedness than the control group (Product Feedback Questionnaire items 1–6, $F(1, 28) = 9.40$, $p = 0.005$). Participants in the experiment group were also significantly more likely to report that motor memory training assisted with reducing absent-mindedness, compared to the control group (Product Feedback Questionnaire items 7–9 and 20, $F(1, 28) = 69.3$, $p < 0.001$). Thus, Hypothesis 2 was strongly supported.

In regard to Hypothesis 3 (participants who used trays with visual feedback will report a better user experience compared to participants who used normal trays), the experiment group was found to have a significantly higher scores on the User Experience Scale compared to the control group ($F (1, 28) = 43.77$, $p < 0.001$). Thus, Hypothesis 3 was strongly supported.

In regard to Hypothesis 4 (participants' positive mental health, residential environment satisfaction, and reported comfort with smart devices will have positive correlations with motor memory training result and negative correlations with absent-mindedness), positive mental health was found to be negatively correlated with visual feedback, motor memory, and absent-mindedness ($r = -0.299$, $p = 0.205$). Residential environment satisfaction was found a positive correlation with visual feedback, motor memory, and absent-mindedness ($r = 0.504$, $p = 0.078$). Reported comfort with smart devices was not correlated with visual feedback, motor memory, and absent-mindedness ($r = -0.024$, $p = 0.926$). Thus, Hypothesis 4 was partially supported.

In regard to Hypothesis 5 (participants' reported level of attention-related errors will have negative correlations with motor memory training result and positive correlations with absent-mindedness), reported level of attention-related errors was found a strong positive correlation with visual feedback, motor memory, and absent-mindedness ($r = 0.771$, $p < 0.05$). Thus, Hypothesis 5 was not supported.

Table 1

Participant Demographics for Experiment 1

Age	
below 18	1 (3.33%)
18–30	17 (56.57%)
30–45	6 (20%)
45–60	4 (13.33%)
over 60	2 (6.67%)
Reported Gender	
Female	14 (46.67%)
Male	16 (53.33%)
Other	0 (0%)
Job	
Employed for wages	17 (56.67%)
Out of work and looking for job	2 (6.67%)
Student	7 (23.33%)
Retired	4 (13.33%)
Unable to work	0 (0%)
Education Level	
Elementary school or lower	1 (3.33%)
Middle School	0 (0%)
High school	1 (3.33%)
Technical/vocational training school	3 (10%)
Bachelor’s degree	16 (53.33%)
Master’s degree	9 (30%)
Doctorate degree of higher	0 (0%)
Living Situation	
Own the place and live individually	1 (3.33%)
Own the place and share with family/others	16 (53.33%)
Rent the place and live individually	4 (13.33%)
Rent the place and share with family/others	9 (30%)
Other	0 (0%)

Physical and Mental Health Condition	
Excellent	0 (0%)
Very good	2 (6.67%)
Good	15 (50%)
Fair	6 (20%)
Poor	7 (23.33%)
Very poor	0 (0%)
Forgot Items Recently	
Yes	21 (70%)
No	9 (30%)

Table 2

Pre-experiment Descriptive Statistics for Experiment 1 (All Assessment Instruments Ran from a Minimum Score of 1 to a Maximum Score of 5)

Metrics	**Mean**	**SD**
PMH Scale	3.400	0.686
RESS	3.127	0.696
ARCES	3.164	0.601
IoT Questionnaire	3.371	0.744

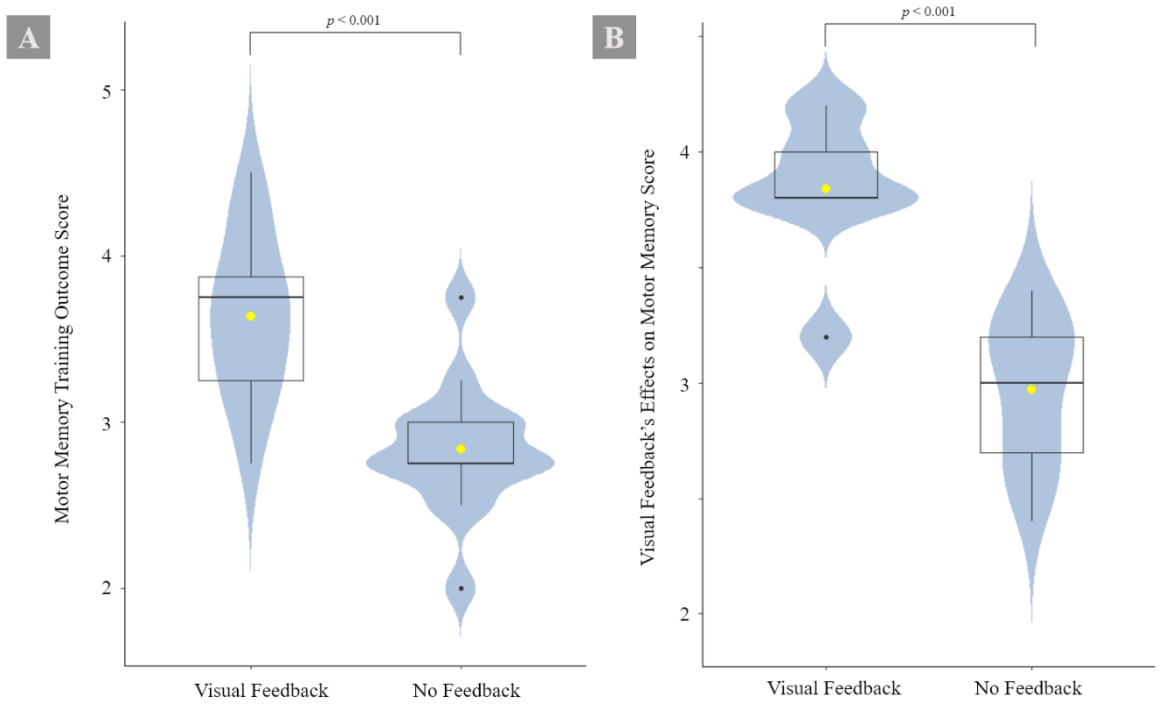
Table 3

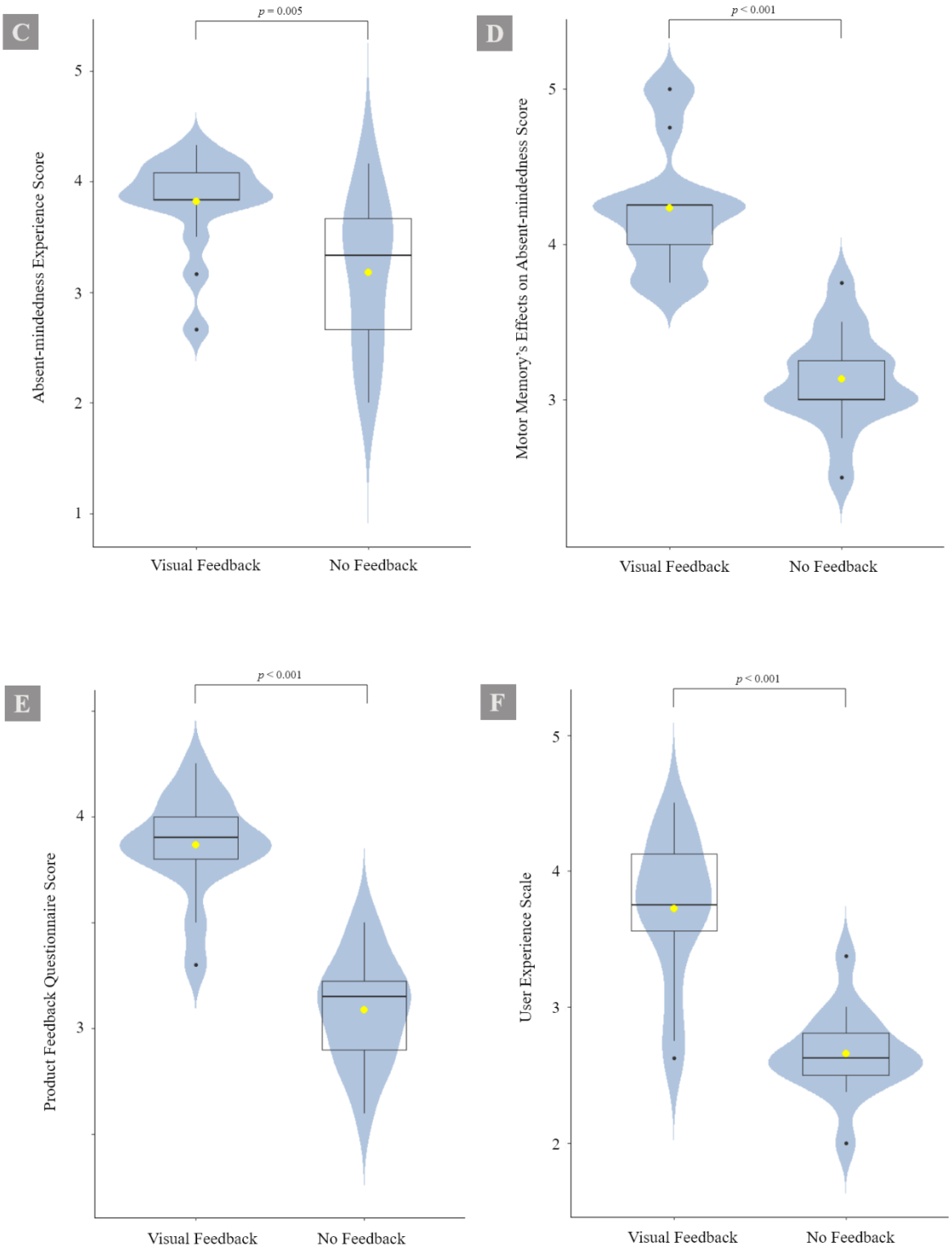
Hypothesis-testing for Experiment 1 (All Assessment Instruments Ran from a Minimum Score of 1 to a Maximum Score of 5)

	Experiment Group (n = 15)		**Control Group (n = 15)**		***p*-value**
Metrics	**Mean**	**SD**	**Mean**	**SD**	
Hypothesis 1: Motor memory training outcome (Product Feedback Questionnaire items 10–12, 18)	3.633	0.473	2.833	0.373	< 0.001
Hypothesis 1: Visual feedback's effects on motor memory (Product Feedback Questionnaire items 13–17)	3.840	0.294	2.973	0.309	< 0.001
Hypothesis 2: Absent-mindedness experience (Product Feedback Questionnaire items 1–6)	3.822	0.415	3.178	0.668	0.005
Hypothesis 2: Motor memory's effects on absent-mindedness (Product Feedback Questionnaire items 7–9, 20)	4.233	0.392	3.133	0.301	< 0.001
Hypothesis 3: User Experience Scale (all items)	3.725	0.525	2.658	0.297	< 0.001

Figure 4

Results of Experiment 1: ANOVA Tests for, (a) the Motor Memory Training Outcome, (b) Visual Feedback's Effects on Motor Memory, (c) Absent-mindedness Experience, (d) Motor Memory's Effects on Absent-mindedness, (e) the Product Feedback Questionnaire, and (f) the User Experience Scale; (Yellow Dots in All Graphs Show the Mean)




C
p = 0.005
Absent-mindedness Experience Score
5
4
3
2
1
Visual Feedback
No Feedback
D
p < 0.001
Motor Memory's Effects on Absent-mindedness Score
5
4
3
Visual Feedback
No Feedback
E
p < 0.001
Product Feedback Questionnaire Score
4
3
Visual Feedback
No Feedback
F
p < 0.001
User Experience Scale
5
4
3
2
Visual Feedback
No Feedback

Experiment 2: Methods

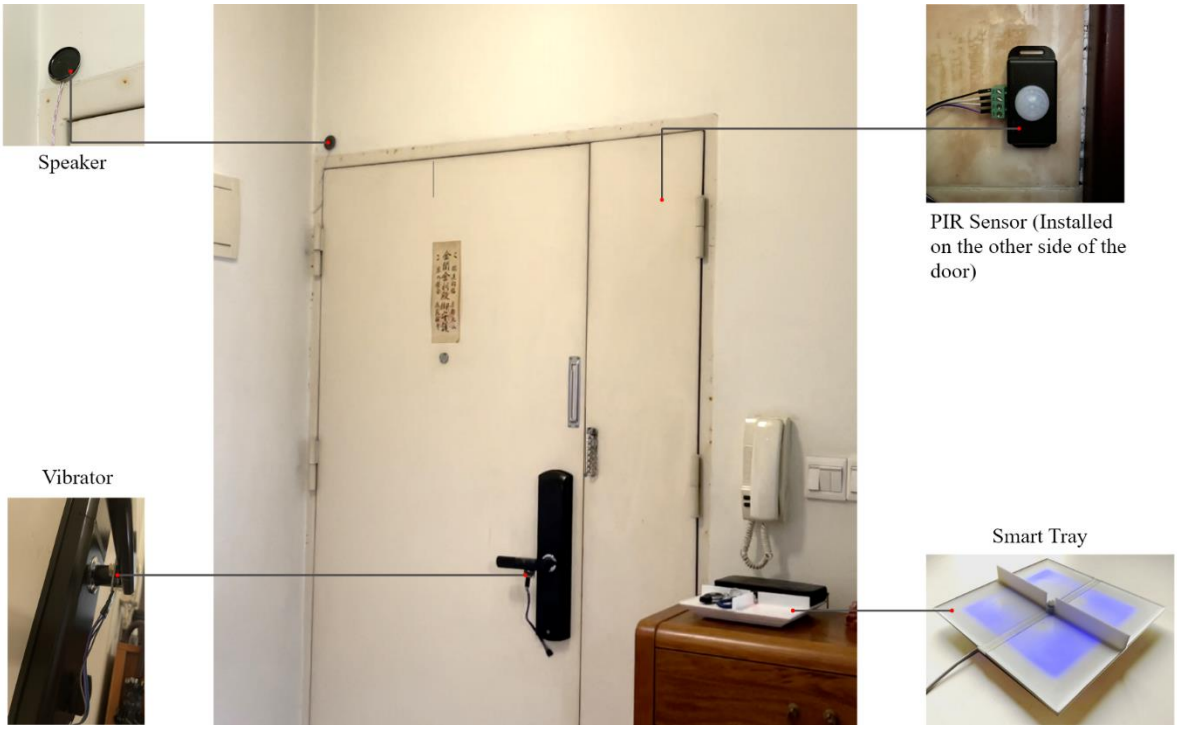
Based on the result of Experiment 1, we were able to draw the conclusion that using the tray with visual feedback was effective in training motor memory and reducing incidents of absent-mindedness related to the placement of small personal items. However, we were also interested to determine how the effectiveness of visual feedback alone would compare to a product that integrated haptic feedback (Bozzacchi et al., 2014) and auditory feedback (Hew & Ohki, 2004; Pardue & McPherson, 2019), in addition to the visual component. Therefore, we carried out a second experiment by modifying the "smart tray" to include multiple forms of feedback.

The Feedback Ecosystem

The new "smarter tray" design incorporated several extra modules that were installed in the participants' residences. These included a door-handle vibrator that would activate if the participant began to exit the house while leaving any item in the tray (haptic feedback), as well as a speaker above the interior door frame that would play a friendly pre-recorded voice message stating: "An item remains on the tray. Please check if you need to carry it" (auditory feedback). In addition, a new passive-infrared sensor was installed next to the exterior door handle, which detected the returning user and triggered the speaker to play a different pre-recorded message: "Welcome back. Please leave your items in the blinking section of the tray" (Figure 5).

Figure 5

The "Smarter" Version of the Tray Included a Speaker, a Door-Handle Vibrator, and an External Passive-infrared (PIR) Sensor to Detect the User's Return



Participants, Procedures, and Metrics

Due to the complexity of installing the feedback system, for Experiment 2 the researchers had to receive the participants' permission to enter their residences. This was further complicated by the continuing effects of the COVID pandemic. Thus, for this experiment we had a small sample consisting of two families, each of which included three adult members. There were six participants in total. Each participant gave free and informed consent, and prior to the experiment the study procedures were reviewed by the IRB **[deleted for the purpose of blind review]**, which determined that the research would pose no risks to human objects. The procedures for Experiment 2 were identical to those for Experiment 1, with the exception that the researchers installed the trays and associated modules at the beginning of the experiment and then removed them at the conclusion of the seven-day trial. The

participants who lived together each used the same tray to store different personal items. The metrics (survey questionnaires) were also identical between Experiment 1 and Experiment 2.

Hypotheses and Data Analysis

Experiment 2 was intended to investigate the effects of adding haptic and auditory feedback to the smart tray (independent variable) on motor memory training outcomes and on the incidence of absent-mindedness (dependent variables). The data collected for the new participant group in this experiment, who used the "smarter tray" with multiple forms of feedback, was compared against the data from Experiment 1 for the basic "smart tray" experiment group (which had visual feedback only). The following hypotheses were tested:

Hypothesis 6. Participants who used "smarter trays" with multiple forms of feedback (visual feedback + haptic feedback + auditory feedback) will have better motor memory performance compared to participants who used trays with only visual feedback.

Hypothesis 7. Participants who received multiple feedbacks and had better motor memory performance will be less affected by absent-mindedness compared to participants who received visual feedback only and had poorer motor memory performance.

Hypothesis 8. Participants who used trays with multiple forms of feedback will report a better user experience compared to participants who used trays with only visual feedback.

To conduct the data analysis, the scores of participants in each of the two experimental groups ("multiple-feedback tray" and "visual-feedback only tray") were averaged on each of the questionnaire instruments. We then conducted ANOVA tests with α level set to 0.05.

Hypothesis 6 was tested by running an ANOVA test to compare the motor memory training outcome between the feedback ecosystem group and the visual feedback group. Items 10–12 and item 18 of the Product Feedback Questionnaire measured participants' subjective opinions on the motor memory training outcomes. Items 13–17 measured the effect of implementing visual feedback on motor memory training. Some questions varied depend on the feedback methods, for instance, item 13 of the Product Feedback Questionnaire answered by the feedback ecosystem group stated "The feedbacks provided by

the tray reminds me to interact with the tray", while item 13 answered by the visual feedback group (the experiment group of experiment 1) stated "The visual feedback provided by the LED lights reminds me to interact with the tray". Some of the items mentioned above were reversely coded to ensure a positive relationship between the score and motor memory training outcomes and feedbacks' effect on motor memory.

Hypothesis 7 was tested by running an ANOVA test to compare the absent-mindedness related experience between the feedback ecosystem group and the visual feedback group. Similar to experiment 1, item 1–6 of the Product Feedback Questionnaire measured participants' experiences of absent-mindedness during the. Item 1-6 were reverse coded which made a negative relationship between the score and the absent-mindedness experience. Items 7–9 and item 20 measured the effect of motor memory training on absent-mindedness. Receiving higher score for those three items represents stronger effect of motor memory on absent-mindedness.

Hypothesis 8 was tested by running an ANOVA test to compare the general user experience between the feedback ecosystem group and the visual feedback group. Participants' user experience and satisfaction rate with the tray products they used were measured and compared. Higher score represents better user experience.

Experiment 2: Results

All 6 of the recruited participants successfully completed the trial and filled out the survey instruments. The demographic data collected from these participants is shown in Table 4. The majority of the participants in this study were women (n=5). They consisted of two families, one of which owned their residence (n=3) and the other of which rented (n=3). Four of the participants reported having recent episodes of absent-mindedness, while two said that they did not have any such recent episodes.

Table 5 describes the participants' scores on the four pre-experiment questionnaires related to potential moderating variables. The scores on these tests again grouped very close to average, with a standard deviation of less than 0.55 (on an 5-point Likert-scale).

Table 6 describes the participants' scores on the two post-experiment questionnaires, and compares them to the visual-feedback-only group from Experiment 1. These scores are broken down according to the response items that were used to test each hypothesis. The detailed results of the ANOVAs that were run for each hypothesis are shown in Figure 6.

In regard to Hypothesis 6 (participants who used "smarter trays" with multiple forms of feedback will have better motor memory performance compared to participants who used trays with only visual feedback), the group with multiple forms of feedback was found to achieve a significantly better reported motor training outcome compared to the visual-feedback-only group (Product Feedback Questionnaire items 10–12 and 18, $F(1, 19)= 7.537$, $p = 0.0129$). However, the participants in the multiple-feedback group were not significantly more likely to report that multiple forms of feedback were a greater help with motor memory development (Product Feedback Questionnaire items 13–17, $F(1, 19)= 0.184$, $p = 0.673$). Thus, Hypothesis 4 was only partially supported.

In regard to Hypothesis 7 (participants who received multiple feedbacks and had better motor memory performance will be less affected by absent-mindedness compared to participants who received visual feedback only and had poorer motor memory performance), the multiple-feedback group was found to experience significantly less absent-mindedness than the visual-feedback-only group (Product Feedback Questionnaire items 1–6, $F(1, 19)= 6.903$, $p = 0.0166$). Participants in the multiple-feedback group were also significantly more likely to report that motor memory training assisted with reducing absent-mindedness, compared to the visual-feedback-only group (Product Feedback Questionnaire items 7–9 and 20, $F(1, 19)= 4.943$, $p = 0.0385$). Thus, Hypothesis 5 was supported.

In regard to Hypothesis 8 (participants who used trays with multiple forms of feedback will report a better user experience compared to participants who used trays with only visual feedback), the multiple-feedback group was found to have a significantly *lower* scores on the User Experience Scale compared to the visual-feedback-only group ($F(1, 19)= 50.27$, $p < 0.001$). Thus, Hypothesis 6 was not supported.

Table 4

Participant Demographics for Experiment 2

Age	
below 18	1 (16.67%)
18–30	3 (50%)
30–45	0 (0%)
45–60	2 (33.33%)
over 60	0 (0%)
Reported Gender	
Female	5 (83.33%)
Male	1 (16.67%)
Other	0 (0%)
Job	
Employed for wages	5 (83.33%)
Out of work and looking for job	0 (0%)
Student	1 (16.67%)
Retired	0 (0%)
Unable to work	0 (0%)
Education Level	
Elementary school or lower	0 (0%)
Middle School	0 (0%)
High school	1 (16.67%)
Technical/vocational training school	0 (0%)
Bachelor’s degree	4 (66.67%)
Master’s degree	1 (16.67%)
Doctorate degree of higher	0 (0%)
Living Situation	
Own the place and live individually	0 (0%)
Own the place and share with family/others	3 (50%)
Rent the place and live individually	0 (0%)
Rent the place and share with family/others	3 (50%)
Other	0 (0%)

Physical and Mental Health Condition	
Excellent	0 (0%)
Very good	0 (0%)
Good	3 (50%)
Fair	3 (50%)
Poor	0 (0%)
Very poor	0 (0%)
Forgot Items Recently	
Yes	4 (66.67%)
No	2 (33.33%)

Table 5

Pre-experiment Descriptive Statistics for Experiment 2 (All Assessment Instruments Ran from a Minimum Score of 1 to a Maximum Score of 5)

Metrics	**Mean**	**SD**
PMH Scale	3.593	0.299
RESS	3.111	0.545
ARCES	2.750	0.289
IoT Questionnaire	2.708	0.509

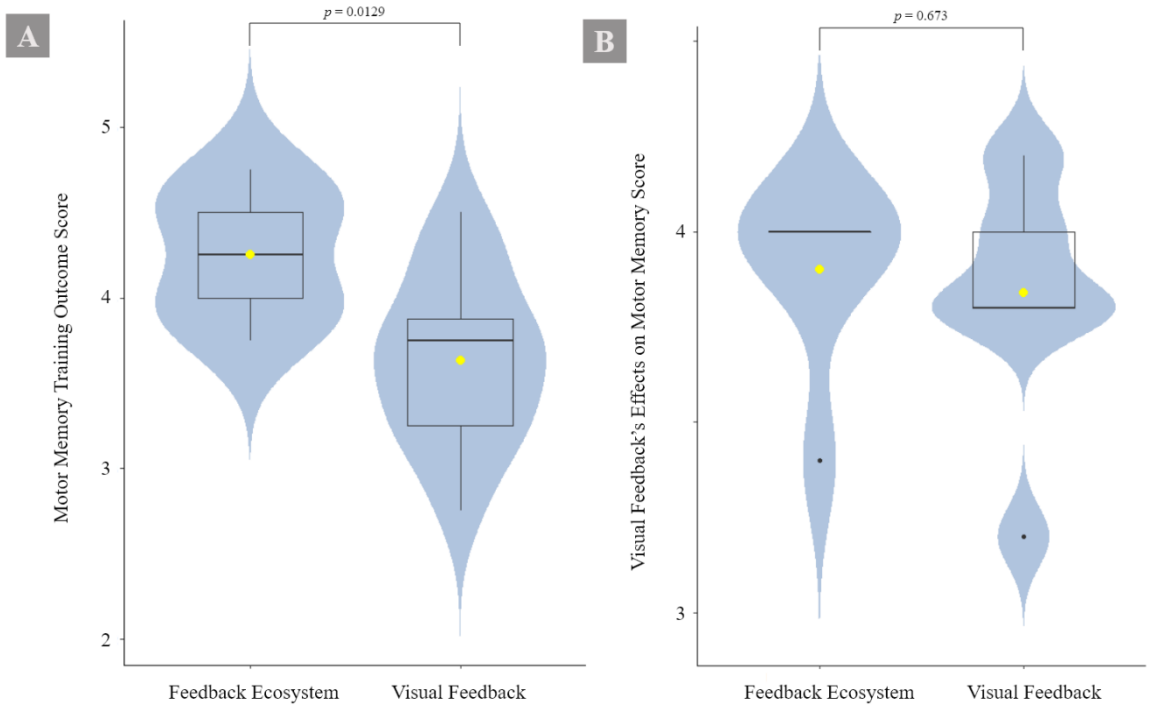
Table 6

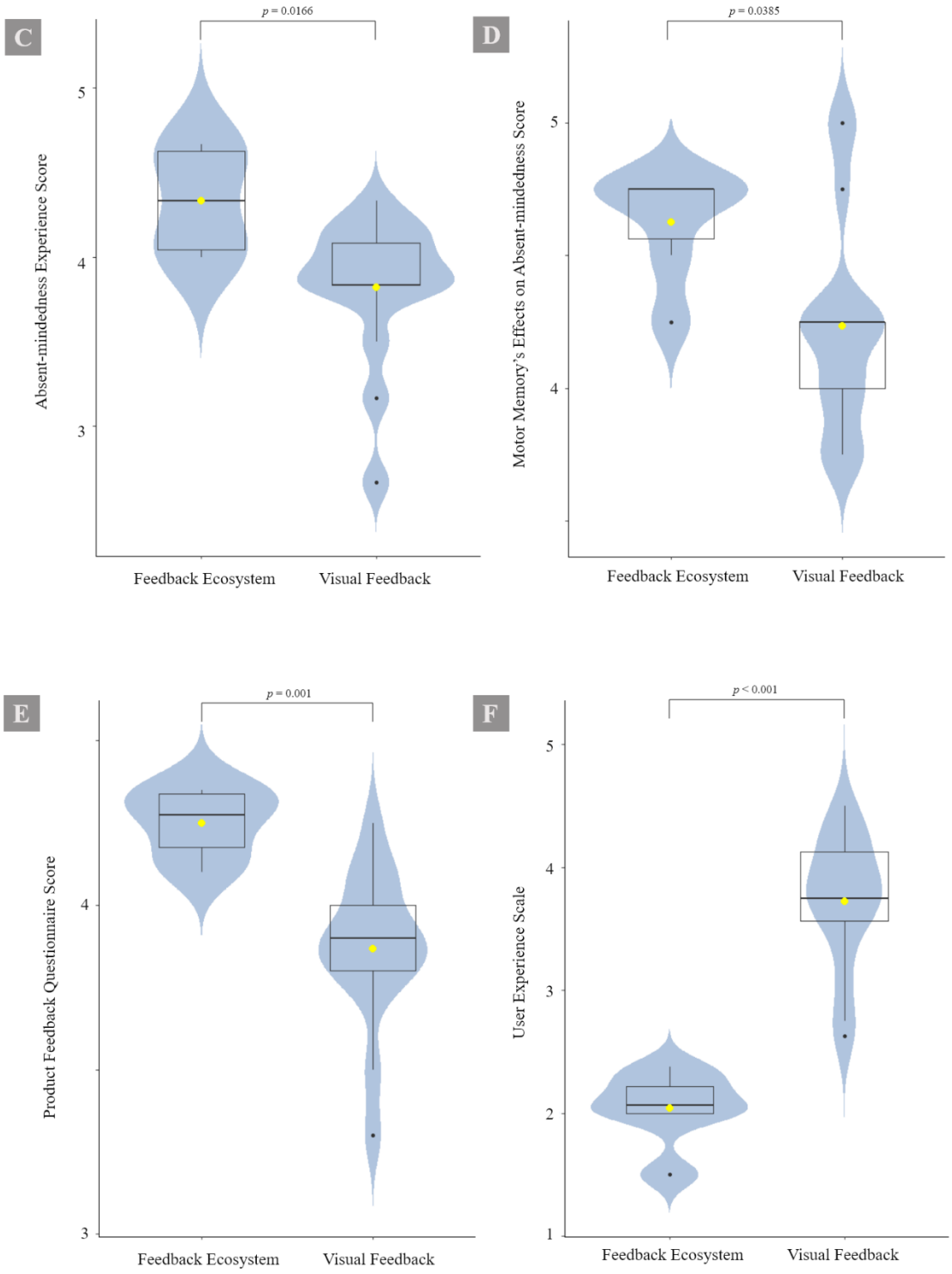
Hypothesis-testing for Experiment 2 (All Assessment Instruments Ran from a Minimum Score of 1 to a Maximum Score of 5)

	Feedback Ecosystem Group (n = 6)		**Visual Feedback Group (n = 15)**		**p-Value**
Metrics	**Mean**	**SD**	**Mean**	**SD**	
Hypothesis 6: Motor memory training outcome (Product Feedback Questionnaire items 10–12, 18)	4.250	0.354	3.633	0.473	0.0129
Hypothesis 6: Visual feedback's effects on motor memory (Product Feedback Questionnaire items 13–17)	3.900	0.224	3.840	0.294	0.6730
Hypothesis 7: Absent-mindedness experience (Product Feedback Questionnaire items 1–6)	4.333	0.289	3.822	0.415	0.0166
Hypothesis 7: Motor memory's effects on absent-mindedness (Product Feedback Questionnaire items 7–9, 20)	4.625	0.191	4.233	0.392	0.0385
Hypothesis 8: User Experience Scale (all items)	2.042	0.276	3.725	0.525	< 0.001

Figure 6

Results of Experiments 1 and 2: ANOVA Tests for (a) the Motor Memory Training Outcome, (b) Visual Feedback's Effects on Motor Memory, (c) Absent-mindedness Experience, (d) Motor Memory's Effects on Absent-mindedness, (e) the Product Feedback Questionnaire, and (f) the User Experience Scale; (Yellow Dots in All Graphs Show the Mean)




C
p = 0.0166
Absent-mindedness Experience Score
5
4
3
Feedback Ecosystem
Visual Feedback
D
p = 0.0385
Motor Memory's Effects on Absent-mindedness Score
5
4
Feedback Ecosystem
Visual Feedback
E
p = 0.001
Product Feedback Questionnaire Score
4
3
Feedback Ecosystem
Visual Feedback
F
p < 0.001
User Experience Scale
5
4
3
2
1
Feedback Ecosystem
Visual Feedback

Discussion and Conclusions

The present study examined whether a new type of "smart tray" for storing small personal items could improve motor memory and mitigate the effect of absent-mindedness through the implementation of visual feedback. The study also tested the effect of visual feedback alone vs. visual feedback accompanied by haptic and auditory feedback. The goal of the smart-tray design was to assist individuals at the moment of absent-mindedness (i.e., when they forgot to place their items in a customary location); this is in contrast to most related electronic products currently on the market, which generally assist in finding objects only after they have become lost.

Using AirTag as an example: although using AirTags would be a more effective and easy solution for users with cognitive disorders, such as previous brain damage, or users who have a hard time understanding the human-computer interaction process because of its convenience that no training session or learning curves is required to use this kind of electronic products, using AirTag can't prevent the happening of absent-mindedness and guarantee users to retrieve their lost items. Instead, using the tray implemented with different types of feedback could inform users before the incidence of absent-mindedness. Interacting with the tray could also help users to develop good habits to avoid forgetful behaviors and benefit their brains. To the best of our knowledge, there are no commensurate products currently available for sale, and no prior research has been carried out to evaluate the effectiveness of this approach to mitigating the effects of absent-mindedness.

The study collected data about potential moderating variables that might affect the relationship between the use of the smart tray and the incidence of absent-mindedness. These variables included participants' positive mental health, their satisfaction with their residential environment, extent of attention lapses, and comfort with using wireless technology in the home.

Only residential environment satisfaction and reported level of attention-related errors was found to have strong moderation effects on the relationship between visual feedback, motor memory, and absent-mindedness. We also found participants' positive mental health condition and reported comfort with smart devices does not have significant moderation effects. However, this outcome was due to a lack

of variability in these factors among our participant population; the scores on the relevant instruments were essentially equivalent across all participants. Future researchers will need to continue looking at these and other possible moderating factors in more depth.

Experiment 1 in the current study compared the effectiveness of visual feedback via the smart tray for improving motor memory and for mitigating the effects of absent-mindedness. The results strongly supported the value of this approach, showing that the visual feedback improved both motor memory and the effects of absent-mindedness, that motor memory improvements were themselves associated with mitigating the effects of absent-mindedness, and also that the participants preferred using the smart tray over an equivalent "dumb tray" that lacked visual feedback. These findings are commensurate with the prior literature discussing the use of visual feedback to achieve better task performance and to reduce attentional lapses (Bozzacchi et al., 2014; Dube & Roy, 2019; Hew & Ohki, 2004); Leech and Roemmich, 2018; Pardue & McPherson, 2019; Shafer et al., 2019).

Other previous studies have suggested that haptic and auditory feedback may also benefit the motor memory training process and mitigate the effects of absent-mindedness (Bozzacchi et al., 2014; Hew & Ohki, 2004). Thus, Experiment 2 was conducted to compare the effectiveness of multiple combined feedback methods vs. visual feedback alone. The results of this experiment were mixed. In general, the findings indicated that multiple feedback methods (visual + haptic + auditory) were more effective at mitigating the effects of absent-mindedness compared to visual feedback alone. However, the participants did not report that multiple feedback methods were a greater help with motor memory development, and they rated the user experience of the tray with multiple feedback methods significantly lower than the tray that only incorporated visual feedback.

In regard to this issue of user ratings, one of the survey questions on which the multiple-feedback tray performed very poorly was item 21 of the Product Feedback Questionnaire, which indicated that the tray was "too distracting." With such low user experience ratings, it is likely that the adoption and regular use of the product would be very limited. This suggests that it is important to find the right balance between feedback that is sufficient to overcome attentional lapses and train motor memory vs. feedback

that is so overwhelming that it becomes an annoyance to the user. For future research and product development, it will be necessary to carefully evaluate both the positive and negative impacts of each feedback method and to find the correct combination of feedback methods to optimize the product's effectiveness.

In terms of future product development, besides adding additional modules that allow the tray to upload users' absent-mindedness data, such as the when did they experience absent-mindedness, and what items did they left behind, to the server, we are thinking of developing an App, or plug-ins for existing Apps, that tracks user's absent-mindedness condition and could remind users whenever they experience absent-mindedness on their smartphones. For the physical form of the tray, we believe it would be better to integrate the customizable storage function of the tray into other furniture, such as a smart door, or a smart stool that is placed near the entrance. In other words, if this idea comes true, when users approach the entrance, some hidden slots on the door will be uncovered so users can pick items from those door slots. There is no need to shift users' attention away to somewhere else.

Limitations

On the first hand, the current research was limited to testing only one specific product and its implementations of visual, haptic, and auditory feedback. Other types of implementation are possible. For example, the current study did not evaluate the latency, color, brightness, or pattern of the visual feedback that was delivered to participants. Future studies should focus on systematically investigating such variables. Adjusting the implementation of haptic and auditory feedback (for example, using a soft beep rather than a pre-recorded voice message) may potentially alter the low user ratings that participants gave to these types of feedback in the current study. Including qualitative data (interviews, open-ended questions, etc.) in future studies may also help in better understanding user responses to the product and optimizing its effectiveness.

On the other hand, our tray products did not have the capability to collect the ground truth on whether the user forgot to pick their items up before leaving because of two reasons. First, the cost issue. We did not have the budget to build fully functional prototypes that is able to connect to the internet and

upload their real-time data to the server. And second, the privacy issue. Because the experiments took place in participants' houses not our labs, so we could not use a camera or other devices to record their behavior patterns each time when they interacted with the trays. Because of those two reasons, we used Likert-scale questionnaires to track users' objective opinion towards motor memory training effect and absent-mindedness related experience for the results. Future studies could focus on designing products that are able to track users' behavior patterns and give feedback whenever they experienced absent-mindedness.

Another important limitation in the study was the small number of participants, especially in Experiment 2, and the limited amount of time that the participants used the products. Logistical restrictions, particularly due to the COVID pandemic, were the reason for these limitations, but future studies should be able to overcome such issues. A larger and more diverse sample size would help in achieving more robust statistical outcomes, and would likely allow for a better evaluation of moderator variables. It will be particularly important to evaluate the product with individuals who have been diagnosed with high levels of absent-mindedness, since that is the primary user target for these products. A longer trial period is also recommended, as it may be necessary for the full benefit of motor memory training to become evident. The "habit-loop" method of establishing behavioral patterns, for example, recommends a 21-day training period (Lally et al., 2009).

Appendix A – Pre-Experiment Questionnaire

Pre-experiment Questionnaire

Consent Form

We are asking you to participate in a research study. I will describe this study to you and answer any of your questions.

Project Title: "There" Tray User Testing
Principal Investigator: Howard Zhang
Email: hz495@cornell.edu
Phone: (+86)15802121775

What the study is about:
The purpose of this research is to design an interactive, habit-forming tray product for the user to place important daily items (keys, car keys, wallets, glasses, etc.) and easily retrieve them when leaving home.

What we will ask you to do:
We will send necessary experiment material to you through a delivery box. You will assemble the tray based on the instructions. You will "use" the tray by placing your important daily items (keys, car keys, wallet, etc.) on it when you come back to your house. After a week when the research is done, you will send back the box to us and fill out a 5-minute-questionnaire on your smartphone.

Compensation for participation:
Each participant will be compensated with 65 RMB through Alipay for participating.

Privacy/Confidentiality/Data Security:
We anticipate that your demographic information and your questionnaire will be private and used only for the study. Only the researcher will have access to the material. Once the study is completed all the files will be saved indefinitely on the personal computer of the researcher for future reference.

Demographic Information (7 questions)

1. What gender do you identify as? *

○A. Male

○B. Female

2. What is your age? *

○A. Below 18 years old

○B. 18 – 30 years old

○C. 30 – 45 years old

○D. 45 – 60 years old

○E. Over 60 years old

3. Are you currently…? *

○A. Employed for wages

○B. Out of work and looking for work

○C. A homemaker

○D. A Student

○E. Military

○F. Retired

○G. Unable to work

4. What is your highest level of education? *

○A. Elementary school or lower

○B. Middle school

○C. High school

○D. Technical/vocational training school

○E. Bachelor's degree

○F. Master's degree

○G. Doctorate degree or higher

5. For the place you are living in, you…? *

○A. Own the place and live individually

○B. Own the place and live with the family

○C. Rent the place

○D. Rent the place and share with other sublessees

○E. Live in a hotel

○F. Other: _____

6. In general, how would rate your health (including mental health condition): *

○A. Excellent

○B. Very good

○C. Good

○D. Fair

○E. Poor

○F. Very poor

7. Have you forgotten any items at home recently? *

○A. If yes, what items: _____

○B. No

Positive Mental Health Scale (PMH-scale) (9 questions)

Items are based on Lukat, J., Margraf, J., Lutz, R., van der Veld, W., & Becker, E. (2016). Psychometric properties of the Positive Mental Health Scale (PMH-scale). BMC Psychology, 4(8). https://doi.org/https://doi.org/10.1186/s40359-016-0111-x.

https://bmcpsychology.biomedcentral.com/articles/10.1186/s40359-016-0111-x#citeas

1. I am often carefree and in good spirits. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

2. I enjoy my life. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

3. All in all, I am satisfied with my life. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

4. In general, I am confident. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

5. I manage well to fulfill my needs. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

6. I am in good physical and emotional condition. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

7. I feel that I am actually well equipped to deal with life and its difficulties. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

8. Much of what I do brings me joy. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

9. I am a calm, balanced human being. *

○Strongly Disagree	○Disagree	○Neutral	○Agree	○Strongly Agree

Residential Environmental Satisfaction Scale (RESS) (15 questions)

Items are based on Adriaanse, C. C. M. (2007). Measuring residential satisfaction: a residential environmental satisfaction scale (RESS). Journal of Housing and the Built Environment, 22(287).

https://doi.org/https://doi.org/10.1007/s10901-007-9082-9

https://link.springer.com/article/10.1007/s10901-007-9082-9#citeas

1. I am satisfied with my dwelling. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

2. The layout of this dwelling is convenient. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

3. The dwelling is well maintained. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

4. The dwelling has a pleasing ambience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

5. The dwelling is well organized. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. I am satisfied with my living environment. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. The buildings in this neighborhood are attractive. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I think living in this neighborhood is a good experience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

9. I don't feel an urge to move out of this neighborhood. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

10. I feel at home in this neighborhood. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

11. I have a lot of contact with my neighbors. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

12. I have a lot of contact with other residents in my neighborhood. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

13. In this neighborhood residents treat each other pleasantly. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

14. People in this neighborhood know each other. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

15. I am satisfied with the social mix of the neighborhood population. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

Attention-Related Cognitive Errors Scale (ARCES) (12 questions)

Items are based on Carriere, J. S., Cheyne, J. A., & Smilek, D. (2008). Everyday attention lapses and memory failures: the affective consequences of mindlessness. Consciousness and Cognition, 17(3), 835–847. https://doi.org/10.1016/j.concog.2007.04.008

1. I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice). *

○Never ○Rarely ○Sometimes ○Often ○Very Often

2. I go into a room to do one thing (e.g., brush my teeth) and end up doing something else (e.g., brush my hair). *

○Never ○Rarely ○Sometimes ○Often ○Very Often

3. I have lost track of a conversation because I zoned out when someone else was talking. *

○Never ○Rarely ○Sometimes ○Often ○Very Often

4. I have absent-mindedly placed things in unintended locations (e.g., putting milk in the pantry or sugar in the fridge). *

○Never ○Rarely ○Sometimes ○Often ○Very Often

5. I have gone into a room to get something, got distracted, and wondered what I went there for. *

○Never ○Rarely ○Sometimes ○Often ○Very Often

6. I begin one task and get distracted into doing something else. *

○Never ○Rarely ○Sometimes ○Often ○Very Often

7. When reading I find that I have read several paragraphs without being able to recall what I read. *

○Never ○Rarely ○Sometimes ○Often ○Very Often

8. I make mistakes because I am doing one thing and thinking about another. *

○Never ○Rarely ○Sometimes ○Often ○Very Often

9. I have absent-mindedly mixed up targets of my action (e.g., pouring or putting something into the wrong container). *

○Never ○Rarely ○Sometimes ○Often ○Very Often

10. I have to go back to check whether I have done something or not (e.g., turning out lights, locking doors). *

○Never ○Rarely ○Sometimes ○Often ○Very Often

11. I have absent-mindedly misplaced frequently used objects, such as keys, pens, glasses, etc. *

○Never ○Rarely ○Sometimes ○Often ○Very Often

12. I fail to see what I am looking for even though I am looking right at it. *

○Never ○Rarely ○Sometimes ○Often ○Very Often

IoT (Internet of Things) Questionnaire (12 questions)

Items are based on Cannizzaro, S., Procter, R., Ma, S., & Maple, C. (2020). Trust in the smart home: Findings from a nationally representative survey in the UK. PLoS ONE , 15(5). https://doi.org/https://doi.org/10.1371/journal.pone.0231615

https://file.scirp.org/Html/3-1760295_51898.htm

1. Have you heard of the expression "Smart Home"? *

○A. Yes

○B. No

○C. I am not sure

2. The following are examples of Internet of things/smart home devices. Please indicate whether you own and use the specified device. *

□A. Wi-Fi-enabled TV

□B. Smart electric or gas meter

□C. Personal home assistants (Amazon Alexa, Google Home, Xiaomi Smart Home)

□D. Wi-Fi Webcam

□E. Remote Home control devices (smart bulbs, blinders…)

□F. Robot vacuum cleaner

□G. Wi-Fi-enabled bathroom Scale

□H. Smart door locks

□I. Wi-Fi-enabled/smart washing machine

□J. Wi-Fi-enabled/smart fridge

□K. Wi-Fi-enable/smart oven

□L. Robotic Lawnmower

□M. Other: _____

3. How many smart devices from the above list do you currently own? _____ *

4. How long have you been using smart home devices in your own home? _____ (Please fill in the unit, for example: 1 month, 2 years, etc.) *

5. The use of the smart features of my smart home devices has become routine. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. I would fully trust smart home devices not to fail, and to function as I expect them to. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. Knowing that smart home devices allow companies or organizations to collect data about how I use them, and hence about my domestic habits, would not restrict me from owning/using them (benevolence). *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I would trust companies not to use data produced by smart home devices for any purpose without my explicit consent (integrity). *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

9. I am ok that the device sharing my data on social media. *

○Strongly ○Disagree ○Neutral ○Agree ○Strongly Agree

Disagree

10. I find that my smart home devices exceeded my expectation. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

11. I intend to use or continue using smart home devices in the future. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

12. I would recommend smart home devices to my friends. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

What is the your code (Please see your delivery box): *

_____

Appendix B – Post-Experiment Questionnaire (Experiment Group)

Post-experiment Questionnaire

We appreciate your participation in this experiment. Please fill the post-experiment questionnaire listed below. Your response and feedback will be carefully reviewed.

Product Feedback Questionnaire (21 questions)

Items were based on Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. Journal of Personality and Social Psychology, 84, 822–848.

And Carriere, J. S., Cheyne, J. A., & Smilek, D. (2008). Everyday attention lapses and memory failures: the affective consequences of mindlessness. Consciousness and Cognition, 17(3), 835–847. https://doi.org/10.1016/j.concog.2007.04.008

1. I usually forget to pick up daily items that I need (e.g., door keys, car keys, wallet, watch) when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

2. I feel nervous when I try to remember and check what daily items I need to carry with when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

3. I have tried different methods to avoid forgetting daily items (e.g., setting up a notification, asking someone to remind me). *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

4. I am in a hurry when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

5. Sometimes I forgot where I place my daily items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. Sometimes I try to find something even though I am looking at it. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. Keeping items in a fixed place makes it easier for me to retrieve them. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I can easily retrieve daily items when I place them in the tray. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

9. Using the tray helps me to remember what daily items I need to carry with. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

10. Using the tray saves my time. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

11. The tray helps me to develop the habit of keeping things organized. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

12. Putting things into the tray is inconvenient. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

13. The visual feedback provided by the LED lights reminds me to interact with the tray. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

14. I believe the tray's LED lights are annoying. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

15. The LED lights are not helpful at all. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

16. I don't understand the meaning of the LED signal. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

17. LED lights grab my attention. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

18. Using a tray with different sections helps me to organize my daily items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

19. I don't understand how to set up tray sections for different items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

20. Placing items at the assigned section helps me to retrieve them. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

21. If you can make any changes to the tray, what will you do? *

_____

User Experience Scale (8 questions)

Items were based on McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. Res. Q. Exerc. Sport, 60(1), 48–58. https://doi.org/10.1080/02701367.1989.10607413

https://pubmed.ncbi.nlm.nih.gov/2489825/

1. I have enjoyed the experience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

2. I would describe the experience as interesting. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

3. I thought the experience was understandable. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

4. I didn't find the experience difficult. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

5. I want to continue to use the product. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. I want to purchase the product. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. I would recommend this product to other people. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I didn't want to end the experience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

What is the your code (Please see your delivery box): *

_____

Appendix C – Post-Experiment Questionnaire (Control Group)

Post-experiment Questionnaire

We appreciate your participation in this experiment. Please fill the post-experiment questionnaire listed below. Your response and feedback will be carefully reviewed.

Product Feedback Questionnaire (21 questions)

Items were based on Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. Journal of Personality and Social Psychology, 84, 822–848.

And Carriere, J. S., Cheyne, J. A., & Smilek, D. (2008). Everyday attention lapses and memory failures: the affective consequences of mindlessness. Consciousness and Cognition, 17(3), 835–847. https://doi.org/10.1016/j.concog.2007.04.008

1. I usually forget to pick up daily items that I need (e.g., door keys, car keys, wallet, watch) when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

2. I feel nervous when I try to remember and check what daily items I need to carry with when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

3. I have tried different methods to avoid forgetting daily items (e.g., setting up a notification, asking someone to remind me). *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

4. I am in a hurry when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

5. Sometimes I forgot where I place my daily items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. Sometimes I try to find something even though I am looking at it. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. Keeping items in a fixed place makes it easier for me to retrieve them. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I can easily retrieve daily items when I place them in the tray. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

9. Using the tray helps me to remember what daily items I need to carry with. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

10. Using the tray saves my time. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

11. The tray helps me to develop the habit of keeping things organized. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

12. Putting things into the tray is inconvenient. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

13. I can remember to put items back to the assigned sections of the tray. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

14. It' makes no sense that the tray has different sections. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

15. The tray is not helpful at all. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

16. I don't know where to put every item into the tray. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

17. The tray grabs my attention. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

18. Using a tray with different sections helps me to organize my daily items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

19. I don’t understand how to set up tray sections for different items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

20. Placing items at the assigned section helps me to retrieve them. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

21. If you can make any changes to the tray, what will you do? *

_____

User Experience Scale (8 questions)

Items were based on McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. Res. Q. Exerc. Sport, 60(1), 48–58. https://doi.org/10.1080/02701367.1989.10607413

https://pubmed.ncbi.nlm.nih.gov/2489825/

1. I have enjoyed the experience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

2. I would describe the experience as interesting. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

3. I thought the experience was understandable. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

4. I didn't find the experience difficult. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

5. I want to continue to use the product. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. I want to purchase the product. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. I would recommend this product to other people. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I didn't want to end the experience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

What is the your code (Please see your delivery box): *

_____

Appendix D – Post-Experiment Questionnaire (Feedback Ecosystem Group)

Post-experiment Questionnaire

We appreciate your participation in this experiment. Please fill the post-experiment questionnaire listed below. Your response and feedback will be carefully reviewed.

Product Feedback Questionnaire (21 questions)

Items were based on Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. Journal of Personality and Social Psychology, 84, 822–848.

And Carriere, J. S., Cheyne, J. A., & Smilek, D. (2008). Everyday attention lapses and memory failures: the affective consequences of mindlessness. Consciousness and Cognition, 17(3), 835–847. https://doi.org/10.1016/j.concog.2007.04.008

1. I usually forget to pick up daily items that I need (e.g., door keys, car keys, wallet, watch) when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

2. I feel nervous when I try to remember and check what daily items I need to carry with when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

3. I have tried different methods to avoid forgetting daily items (e.g., setting up a notification, asking someone to remind me). *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

4. I am in a hurry when leaving the house. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

5. Sometimes I forgot where I place my daily items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. Sometimes I try to find something even though I am looking at it. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. Keeping items in a fixed place makes it easier for me to retrieve them. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I can easily retrieve daily items when I place them in the tray. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

9. Using the tray helps me to remember what daily items I need to carry with. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

10. Using the tray saves my time. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

11. The tray helps me to develop the habit of keeping things organized. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

12. Putting things into the tray is inconvenient. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

13. The feedbacks provided by the tray reminds me to interact with the tray. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

14. I believe the feedbacks are annoying. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

15. The feedbacks are not helpful at all. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

16. I don't understand the meaning of the feedbacks. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

17. The feedbacks grab my attention. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

18. Using a tray with different sections helps me to organize my daily items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

19. I don't understand how to set up tray sections for different items. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

20. Placing items at the assigned section helps me to retrieve them. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

21. If you can make any changes to the tray, what will you do? *

_____

User Experience Scale (8 questions)

Items were based on McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. Res. Q. Exerc. Sport, 60(1), 48–58. https://doi.org/10.1080/02701367.1989.10607413

https://pubmed.ncbi.nlm.nih.gov/2489825/

1. I have enjoyed the experience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

2. I would describe the experience as interesting. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

3. I thought the experience was understandable. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

4. I didn't find the experience difficult. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

5. I want to continue to use the product. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

6. I want to purchase the product. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

7. I would recommend this product to other people. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

8. I didn't want to end the experience. *

○Strongly Disagree ○Disagree ○Neutral ○Agree ○Strongly Agree

What is the your code (Please see your delivery box): *

_____

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