Understanding the Role of Human Senses in Interactive Meditation

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ABSTRACT
In our fast-paced society, stress and anxiety have become increasingly common. Meditation for relaxation has received much attention. Meditation apps exploit various senses, e.g., touch, audio and vision, but the relationship between human senses and interactive meditation is not well understood. This paper empirically evaluates the effects of single and combined human senses on interactive meditation. We found that the effectiveness of human senses can be defined by their respective roles in maintaining the balance between relaxation and focus. This work is the first to attempt to understand these relationships. The findings have broad implications for the field of multi-modal interaction and interactive meditation applications.

ACM Classification Keywords
H.5.m [Information Interfaces and Presentation]: Miscellaneous.

Author Keywords
Human senses; interactive meditation; relaxation, mindfulness, focus.

INTRODUCTION
73% of Americans regularly experience stress symptoms [34] thus mindfulness meditation has received much attention among researchers [7, 24, 27, 35, 36, 39, 43]. Meditation [11, 23, 28] is widely defined as practices or techniques that cultivate mindfulness, a state of moment-to-moment non-judgmental awareness [16, 42]. Abundant evidence supports the efficacy of meditation, e.g., for improving brain function [44], improving emotion regulation [2, 9], and increasing well-being [22]. Given their prevalence, smartphones provide viable platforms to support meditation with more than 300 meditation relaxation apps in app stores. Since attention and relaxation are mediated through the human senses, meditation apps can be categorized according to the human senses [4, 32]. In this paper, we focus on the three most commonly used senses applied in smartphone meditation apps: audio, vision, and touch.

Audio-based meditation comes in many forms. For example, in Mantra meditation, practitioners repeatedly chant a mantra [3]. Nature sounds and singing bowl sounds have also been used [1, 12, 19, 21, 30]. *Vision-based* meditation comes mainly in the form of gazing at the shape of neutral visual stimuli such as nature scenes [40], calming visualizations [33, 38], a burning candle, or a lava lamp [6]. This has since been verified by Attention Restoration Theory [17] which states that spending time with soft cognitive stimuli such as a forest or an ocean can lead to a state of meditation. *Touch-based* (sometimes called body-based) meditation exploits the principle of relaxation response theory [14] which states that slow deliberate movement can stimulate heightened attention. This principle is reflected in many traditional meditation methods such as Tai Chi, Yoga and Qigong [14, 31]. One example of touch-based meditation apps is to focus on one gentle, slow finger movement on the smartphone screen [5, 29]. Moreover, several meditation apps also leverage combinations of audio, vision and touch to support meditation.

Prior studies reveal that little evaluative work has been done on the effects of the various human senses in meditation relaxation applications. The main goal of this paper is to understand how different human senses affect relaxation experience while using meditation apps. How does vision-only compare with audio-only meditation? Do combinations of senses, e.g., vision+audio facilitate relaxation better than single sense apps e.g., vision-only? How do subjective preferences affect relaxation? Our findings will allow designers to better exploit the senses in meditation apps and also in multi-modal interaction in general.

DEFINITION
Meditation is a complex construct and has various theoretical underpinnings which we cannot cover at length in a note. Instead, this note looks at meditation from the perspective of *Concentrative Meditation* (CE). CE is a popular form of meditation asking practitioners to focus on one object (e.g., audio, a visual image, a body action) and sustain it over a period of time [39]. CE can be further described in two phases: analytical and placement [13]. In the analytical phase, users reflect on an object of meditation to help introduce or restore their attention. In this phase, judgmental effort is still involved. When users feel calm and still, they gradually enter the placement (or the actual meditation) phase. In this phase, users

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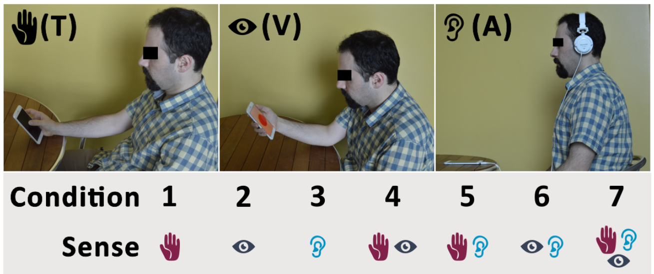

Figure 1. Mobile apps exploit different senses for interactive meditation. This study investigates the effects of touch (T), vision (V), audio (A) and their combinations on meditation app use.

experience a state of non-judgmental awareness, i.e., they are just aware of their thoughts coming and going. Whenever users become distracted, they repeat the analytical phase to restore the meditative state. Our work was grounded upon these definitions.

USER STUDY

The main goal of this study is to define how human senses affect meditation experiences. We compared the effects of audio, vision, touch and their combinations (see Figure 1) using a within-subject design. Our experiment was based on Pause[1] [5, 29] as a case study which supports three modalities of meditation and has also been shown to be an effective tool for meditation.

Conditions

Touch (T). The Touch condition required participants to slowly and continuously perform circular movements with one finger on the touchscreen. One finger was preferred over multi-touch movement because it allows users to focus the attention on one point and to minimize effort. Participants were instructed to close their eyes when they wanted to, while maintaining finger movement.

Vision (V). The Vision condition used amorphous visual feedback using floating bubbles with a wide range of calming colors [20]. Each participant was free to choose the color they preferred. We did not choose a nature view e.g., the sea or a waterfall, because scene preferences vary greatly from person to person. Instead, we chose more neutral visual stimuli that nevertheless had calming and soothing effects. Participants were asked to focus on the dynamic changing shape of the floating bubbles. Participants were instructed to close their eyes when they wanted to, and when they did so, they were asked to sustain their attention by visualizing the floating bubbles in their minds.

Audio (A). The Audio condition combined instrumental music with background nature sounds. We did not choose guided or mantra meditation given the possible confounding effect of the teacher's guidance. In addition, guided or mantra meditation requires prior training and this was not considered to be suitable for our experiment. Participants were simply instructed to listen to the audio, and close their eyes whenever they wanted to.

Touch and Visual (T+V). T+V is an interaction mechanism using both touch and vision. When users touch and move a finger slowly and gently on the screen, the floating bubble slowly increases in size until it fills the whole screen. On the other hand, whenever the finger movement is interrupted (e.g., by lifting the finger or when movement was too fast or stalled), the floating bubbles slowly decrease in size.

Touch and Audio (T+A). T+A is an interaction mechanism combining touch and audio. When users move a finger slowly, gently and continuously on the screen, the audio keeps playing, otherwise, the audio stops to alert the participants.

Audio and Visual (A+V). Participants were simply asked to reflect on the floating bubbles while listening to the background audio.

Touch, Audio and Visual (T+A+V). Participants were asked to gently perform the finger movement while the floating bubbles and audio served as feedback mechanisms.

Apparatus

We allowed users to choose their preferred smartphone sizes in order to promote comfortable interaction. We provided a 4-inch (Fleaz F4s+), a 4.5-inch (Alcatel OneTouch POP C5 Dual 5036D), a 4.65-inch (Samsung Galaxy Nexus I9250) and a 5.7-inch (Samsung Galaxy note 3). We used a polar H7 heart rate sensor to measure heart rate.

Participants

Seventeen university students (10 females, age 24 to 35, $M = 28.6$, $SD = 4.0$) volunteered for the study. One participant had prior experience in meditation, while the rest of the participants had never experienced meditation. A power analysis indicated that our sample size has a 95% chance of detecting a moderate effect ($d = 0.5$) with power set at 0.8.

Procedure

First, we explained the study procedure to participants. Then participants were asked to choose their preferred smartphone sizes. A heart rate sensor was fixed around the participant's chest and the quality of the signal was checked. Participants were asked to choose a comfortable sitting posture, and to breathe deeply and slowly for two minutes. Then they were taught how to practice meditation using the assigned condition. They were asked to meditate using the assigned condition for 10 minutes. After each condition, participants took a rest for five minutes while answering questionnaires. All seven conditions were completed in two days, three conditions on the first day and the rest on the second day. The order of intervention was completely randomized across participants. At the end of the second day, we conducted a semi-structured interview. We also asked participants to rank their preferences and ease of use for each of the seven conditions.

Metrics

We reviewed and identified common evaluation methods described in prior studies. The effectiveness of meditation can be measured by psychological metrics such as questionnaires and interviews and physiological metrics via quantitative measuring tools such as heart rate sensors. We applied the following metrics: *Relaxation Technique Rating Scale* (RTRS) is commonly used to measure the level of relaxation [10]. To understand how the human senses affect user motivation, we used the *Intrinsic Motivation Inventory* (IMI) [8] containing three subscales - importance, enjoyment and usefulness. To understand how participants prioritize each of the senses, we asked the participants to order the seven conditions according to their preferences and ease of use. To understand each participant's rationale, we conducted a semi-structured interview. We also measured Delta Heart Rate as a physiological

[1] www.pauseable.com

Table 1. Results of IMI (Enjoyment, Usefulness and Importance), RTRS, HR Delta (Max-Min), and user preferences and ease of use. The characters (a to i) refer to significant differences between pairs.

Senses	IMI						RTRS		HR Delta		Preference		Easiness	
	Enjoyment		Usefulness		Importance									
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
T	27.59	4.43	27.29	4.01	19.29	1.99	42.41	6.98	14.23[a]	3.86	3.35[a,b,c,d]	1.80	3.25[a,b]	1.80
V	26.47[a,b,c,d]	4.40	25.18[a,b]	7.16	19.06	1.92	38.76[a,b,c]	8.30	17.12	6.89	3.41[e,f,g,h]	2.29	3.25[c]	2.26
A	31.06[a]	5.38	33.18[a,c]	6.39	20.12	2.23	46.23[a]	8.71	15.41	5.71	6.18[b,f,i]	1.51	6.12[b,c]	1.54
T+V	28.47[c]	4.68	27.29[c]	5.99	19.71	3.10	41.47	7.32	17.59	7.79	3.41[g]	1.66	3.50	1.67
T+A	29.82	5.01	31.29	7.28	20.12	2.69	44.41	8.529	17.76[a]	5.42	4.41[a,e]	1.62	4.44[a]	1.67
A+V	29.06[b]	4.64	28.59	7.17	19.41	3.52	44.53[b]	8.12	16.59	4.42	3.70[c,h]	1.61	3.75	1.65
T+A+V	29.29[d]	3.87	30.53[b]	5.66	19.76	2.95	45.18[c]	7.64	18.23	5.98	3.59[d,i]	2.03	3.75	1.98

measurement of relaxation, where delta means the difference between maximum and minimum heart rates while practicing meditation [15, 37, 41].

Results

To analyze IMI, RTRS, and heart rate results, we used Repeated Measures Analysis of Variance (RM-ANOVA) and we used Mauchly's test for correcting the data. Posthoc comparisons with Bonferroni correction were used. The order of user preferences and ease of use were analyzed using the Friedman test and Wilcoxon signed-rank tests for pairwise comparisons. The correlations between user preferences and IMI, RTRS and delta heart rate were analyzed via a Spearman's rank-order correlation test.

Quantitative

Table 1 summarizes the quantitative results. There is a main effect on enjoyment ($F_{4.5,72.2} = 4.145$, $p < 0.01$, $\eta^2 = 0.206$, Mauchly not sig.). Posthoc tests reveal significant differences between V and A ($p < 0.001$), between T+V and V ($p < 0.05$), between A+V and V ($p < 0.01$), and between T+A+V and V ($p < 0.05$). There is also a main effect regarding the usefulness of human senses in the practice of meditation ($F_{4.8,76.9} = 5.155$, $p < 0.001$, $\eta^2 = 0.244$, Mauchly not sig.). Post hoc tests reveal significant differences between V and A ($p < 0.01$), between V and T+A+V ($p < 0.05$), and between A and T+V ($p < 0.01$).

There is a main effect on RTRS ($F_{4.0,64.1.9} = 2.933$, $p < 0.05$, $\eta^2 = 0.155$). Posthoc comparisons reveal significant differences between A and V ($p < 0.01$), between A+V and V ($p < 0.05$), and between T+A+V and V ($p < 0.05$).

There is a main effect on delta (max-min) heart rate ($F_{4.1,65.5} = 2.01$, $p < 0.05$, $\eta^2 = 0.112$, Mauchly not sig.). Post hoc comparisons revealed significant differences between T+A and T ($p < 0.05$).

There is a main effect on preference ($\chi^2(6) = 38.521, p < 0.001$). Post hoc analyses revealed significant differences between T+A and T ($p < 0.01$), between A and T ($p < 0.001$), between A+V and T ($p < 0.05$), between T+A+V and T ($p < 0.01$), between T+A and V ($p < 0.01$), between A and V ($p < 0.001$), between T+V and V ($p < 0.05$), between A+V and V ($p < 0.001$), and between T+A+V and A ($p < 0.01$). We also found a main effect on easiness ($\chi^2(6) = 22.921, p < 0.001$). Post hoc analysis showed significant differences between A+T and T ($p < 0.05$), between A and T ($p < 0.001$), and between A and V ($p < 0.001$).

A Spearman's rank-order correlation was conducted to determine the relation between user preferences and IMI. There was a moderate positive correlation between user preferences and enjoyment ($r_s(119) = 0.339$, $p < 0.001$), a strong positive correlation between user preferences and usefulness ($r_s(119) = 0.524$, $p < 0.001$), and a strong positive correlation between user preferences and (RTRS) ($r_s(119) = 0.414$, $p < 0.001$). These results suggested that preferences affect the effectiveness of meditation.

In general, all measures provide consistent results. We found that A generally performed better than V and T. In addition when V and T were combined with A respectively, the performance of V and T improved, suggesting that A is a significant component. Conversely, we found that when A was combined with other senses, performance was less effective than with A alone. Indeed, this was clearly reflected in user preferences and ease of use. To understand why this was so, we further analyzed our interview results using an open coding process.

Qualitative

Interviews provide a rationale for our quantitative results, particularly on why A was strongly preferred, but also revealed that our quantitative results may not fully depict the complete understanding of V and T. In the interview, all participants reported that, because A is simple and it relaxes them easily, A was strongly preferred. Nevertheless, some participants mentioned that A easily caused them to feel sleepy or their minds to wander. Conversely, most participants reported that both T and V were difficult to practice and required extra effort and thus were not preferred. For example, a participant said, *"Vision is helpful at the beginning to help me focus, but I started to feel tired after a while. Thus I choose to close my eyes but during that time there is literally nothing to keep my attention"*[P4]. Similarly, another participant said that *"Using touch is a useful technique to keep me focused and attentive, but doing it continuously could be tiring. Instead, I prefer touch for several minutes, then I close my eyes once I feel I want to and I can stop/restart the finger movement anytime."*[P15]. To further understand when T and V start to feel tiring, we asked participants at what stage they wanted to close their eyes and stop watching or touching the screen. On average, participants preferred to stop after 4 minutes for vision and after 2 minutes for touch. Participants preferred to close their eyes while maintaining finger movements for a short while; when they felt they were 'in the zone', they wanted the option to stop finger movement altogether so they could enter a deeper mindfulness zone.

These qualitative results contradict our quantitative results, i.e., they indicate that V and T may be actually useful but not preferred, most likely because they promote attentiveness rather than relaxation which can sometimes feel tiring and tense especially for meditation novices. One participant mentioned, *"Everyone strongly preferred audio because audio is easy to practice. Meanwhile, touch and vision require practice and initial effort to train the attention, and they make*

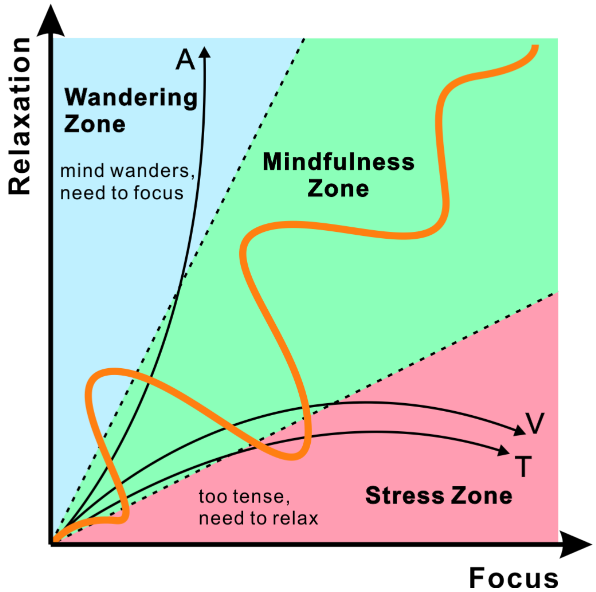

Figure 2. We found that the effectiveness of human senses can be described by their role in maintaining the balance between relaxation and focus. For example, A is useful for relaxation but may easily lead to sleepiness or a wandering mind. On the other hand, V and T are useful for promoting focus but they may cause stress after a period of time. Thus it is important to know how to use the different human senses situationally to maintain both relaxation and focus.

me feel fatigued, tired and it's hard to relax."[P14]. Consistent with our quantitative results, we found that participants mostly focused on the relaxation aspect of meditation, while few appreciated the attentiveness aspect of meditation. This is a very surprising result indicating that lack of participant preferences for certain senses may not mean that these senses are unimportant. Instead, it may suggest the need for users to practice more to enhance their attentive skills. Furthermore, it suggests that perhaps certain senses may be more useful for certain purposes. Specifically, this result indicates that there are two components for meditation. One is relaxation and the other is focus. On the one hand, some interaction conditions (i.e., T and V) lead to focus (but are tiring after a period of time), while on the other hand, some interaction conditions (i.e., A) make people relax (but may lead to drowsiness and a wandering mind).

Interaction between the two components was further observed when participants were asked about combinations of senses. For example, several participants commented that combining T with A or V with A was particularly effective. A participant said, *"Combining touch with audio is better than using touch or audio individually. Touch helps me focus but feels tiring after a long time while audio makes me feel sleepy after a certain period of time. Using both senses addresses both limitations"*[P2]. We found similar comments for the A+V condition.

Overall, this is an interesting result because, (1) it indicates the difference between using human senses for either focus or relaxation, (2) it suggests that V and T are effective for focusing, (3) A is useful for states of relaxation, and (4) both relaxation and focus need to be developed in parallel and eventually integrated, in order to lead users to reach the mindfulness zone.

DISCUSSION AND CONCLUSION

Our findings raised a conflict in the experience of the participants but this conflict helps us understand more precisely the interaction between human senses and meditation. As opposed to our original expectation that certain senses are more effective, we found that the effectiveness of human senses can be defined by their respective roles which are based on the two components of meditation: relaxation and focus (see Figure 2). When users wander or get sleepy, V and T can be helpful to trigger focus. On the other hand, when users feel stress, it may be beneficial for users to stop using V and T and use A instead. Careful configuration and situational application should aim at leading the practitioner into the mindfulness zone, i.e., a state in which relaxation and focus are not in opposition to each other. We suggest that an informed meditation app design must include awareness of various outcomes: relaxation, focus and mindfulness.

Our work is predominantly exploratory but also provides initial design insights. For example, since users may switch between wandering and stress, the effectiveness of a meditation app could be enhanced if it supports a dynamic understanding of the user states (e.g., through biofeedback devices). Another good example is that it may not always be wise to design a dependent interaction mechanism. For example, the dependent mechanism between T and A may prevent users from entering into a more mindful state.

One limitation of our work is the choice of participants, i.e., primarily university students. Our work is also based on a specific prototype thus further study may need to be conducted to confirm our results. Another possible limitation is the limited physiological metric being used. EEG is a common metric for measuring meditation, but we decided not to use EEG as there was evidence that finger movements may affect the results of EEG [18, 25], and thus such EEG results may confound meditation effects and results. Heart rate and respiratory dynamics are generally similar during the relaxation state [26], thus we decided to stick with heart rate while complementing it with qualitative results.

Due to recent evidence regarding the effectiveness of meditation, many developers became excited and applied meditation practice to smartphones but perhaps without adequate understanding. In particular, meditation is an activity that has to account for the human senses where the aim is to reach a mindful state. Thus we intended to scrutinize how human senses affect meditation experiences. Our evaluation approach centered around interactions and multi-modalities (individual and combined) and therefore our findings have significance beyond meditation apps to interactions and interfaces in general. Our work has also opened a discussion regarding how passive interaction such as audio and active interaction such as touch affects the meditation process. This paper can serve as a stepping stone towards understanding the relationship between the human senses and interactive meditation in particular, and multi-modal interactions in general.

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