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Research Article

Examining Potential of Scents for Enhancement of User Performance with Mobile Apps

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Intelligent mobile phones, or simply smartphones, have seen a large widespread usage among the entire world population during the last years. These devices are, in fact, considered as an essential tool in our current day to day life activities. Aromatherapy could be defined as the medical usage of essential oils derived from diverse types of vegetables. Although this paper does not look through direct medical usages or benefits, it is focused on one of its main effects, the stimuli to enhance focus. This study makes use of one of the main essential oils, rosemary, as olfactory stimuli over regular users performing a set of tasks with mobile apps. Results of the experimental group, when compared to regular users not affected with olfactory stimuli, aim to suggest that there is not a clear impact on mobile users' performance. Nonetheless, more research is needed to categorize the effects of aromatherapy on mobile users.

1. Introduction

Intelligent mobile devices, simply referred to as smartphones, are considered in our current society as an essential tool in our day to day activities [1,2]. This is reflected in the fact that each year from 2015 to 2021 has seen sales of around 1.5 million units of smartphones worldwide (while the COVID19 situation slightly reduced 2020 year sales to 1.3 million units) [3].

One of the inherent reasons behind smartphone popularity has been the fact that they are able to host and run mobile apps (software designed to be used in those smartphones). Unsurprisingly, their number is also high, although it is true that there has been a reduction in the number of available apps starting at the beginning of 2018 (one million apps less in Google Play Store [4] and six thousand apps less in Apple App Store [5], dated by the end of 2018). At the beginning of the second quarter of 2021, the number of available applications was 3.48 million apps in Google Play Store and 2.22 million apps in Apple App Store [6].

Among those apps, mobile instant messaging (MIM) apps (for example, WhatsApp, WeChat, Telegram, among others) have acquired a high popularity as an economical alternative to SMS, incorporating more social features compared to those traditional systems, and technologically more accessible to users (including, among others, voice or video calls options) [7,8]. The estimated number of active instant messaging users at the end of 2020 was 2.77 billion of users [9].

There are, nonetheless, some arising issues on security and privacy over MIM apps usage. Based on the findings of Koyuncu and Pusalti [10], showing that user's mobile security awareness is considerably low compared to computers' security awareness. Message transmissions are not secured and private as they should, as derived from Conti *et al.* [11], Johansen et al. [12], and Aceto et al. [13,14] researches on network traffic analysis. Additionally, and related to privacy issues, some studies have pointed out that there are no clear privacy policies for users, leaving unanswered (either unexplicit or complex to understand) how data are managed by the app [15–18].

However, having a new effect in the messaging applications could enhance users' experience. In the current MIM applications, text, audio, images, and Emoji icons have been incorporated in these applications. In addition to these effects, mulsemedia [19,20] could be employed to enhance the interaction between users and messaging applications. Mulsemedia aims to integrate two or more media that involve all human senses such as olfaction and tactile in order to enhance users' QoE [21–25] and users' performance [25–31].

In this paper, we detail the results of an experimental study that explored the impact of olfactory stimuli on current mobile apps users' experience in the context of instant messaging apps. Whilst continuous media such as video and audio rely on playback at a constant rate in *time*, olfactory media do not have this constraint and display a lingering effect in *space*. The challenges of integrating olfactory media with traditional audio-visual content are due on the one side, to this loose coupling between traditional and nontraditional media [32], and on the other, to the issue of identifying application areas of olfactory media in a digital context [33,34]. Indeed, whilst olfaction has been used in the physical, nondigital world for enhancing task performance and memory recall, the transition between the physical, nondigital world to the digital one is not straight forward [35]. Accordingly, the rest of the paper is structured as follows: Section 2 presents a background context for this study. Section 3 presents the methodological elements to carry out the experiment. Section 4 presents the results. Statistical analysis has been applied to determine if there are values that are statistically significant. Finally, Section 5 draws conclusions and highlights opportunities for future work.

2. Related Work

Building on research that has shown the potential of using suitably tailored multimedia content to enhance user's information assimilation [36–38], many opportunities to have olfactory media (media engaging the sense of smell) integrated with other traditional media to aid users' information retrieval and recall were explored. To this end, authors in [25,29,39] investigated the impact of olfactory-enhanced videos on users' performance regarding information recall. In Ademoye and Ghinea [29], participants were asked to watch six 90-seconds videos where an associated olfactory media was synchronised in the second 30-second time window for each video. After that, they asked participants to answer a short quiz regarding the videos. In the same context, Ghinea and Ademoye [25] synchronised olfactory media (related/unrelated) with video content to investigate the impact of that on user perception. In related work, Suzuki et al. [40] enhanced TV videos with olfactory media. Specifically, they customized olfactory-enhanced captions that were emitted and associated with scenes.

Olfactory media has also been shown to aid users' concentration and help them focus and pay attention. In this regard, Miyaura et al. [41] explored using olfactory media to revive users' concentration in different tasks once it decreases. For example, they asked users to track a movement of a small ball within a square on a computer screen using mouse, and they used olfactory media to draw a user's attention when their concentration gets low. In the same field, Ramic-Brkic and Chalmers [42] designed a virtual environment system in which they investigated the ability of participants to observe changes in animation quality from high quality to variable quality under three different situations: without scent, before-scent, and through-scent. In all conditions, they asked users to stop the animation once they observed any change in the quality. They found that the through-scent situation helped to delay the time needed to discern the low quality. Their findings indicated the possibility to reduce the cost of computations in term of quality by benefiting from the olfactory media. In a similar study, tn related work, Brkic et al. [43] performed a study to examine the ability of users to distinguish between two olfactory-enhanced animations in terms of high and low quality, whereas Harvey et al. [50] studied the effects of olfaction on the variation in visual attention.

With respect to task and user performance, Stafford et al. [51] built a dictionary of words and matched each one of them with associated scents depending on the users' opinions. Participants were asked to retrieve these words once they received associated scents. The impact of using olfactory media to aid in a LEGO task formed the focus of [52], where authors investigated the impact of having olfactory media in both training and assessment session on user performance regarding transferring knowledge using different levels of scents. A significant difference was found with regard to the number of critical errors.

In order to enhance realism and user performance, Kwok et al. [27] investigated the impact of olfactory-enhanced classrooms on learners' effectiveness and sensation. To this end, they provided classrooms with smell diffusers. For example, an apple scent was synchronised with piano music and words, all with encouraging results. In the same environment, namely, classrooms, Richard et al. [50] tested the effects of adding haptic and olfactory media on students' learning, information retrieval, and mental associations. Garcia-Ruiz et al. [51] also investigated the effects of having olfactory-enhanced reading tasks on learners' achievement, again with promising outcomes.

There have been continuing attempts to enhance the engagement of users with different applications. More recently, Covaci et al. [34] used two versions of olfactory-enhanced games (PC and mobile) to enhance learners' cognitive, performance, and knowledge development. Then, they compared this with nonolfactory versions. Their findings indicated that olfaction-enhanced educational games improved learner performance, and the participants enjoyed in the olfaction-based game scenario. In chatting and voicemail, Xiang et al. [52] argued that olfactory media and emoticons help the user to send and receive their emotions. They proposed nine emoticons to express the relationship between these nine scents and corresponded emotions. For example, the apple scent used to convey happiness, gratitude, and love emotions.

Table 1 presents a summary of the main characteristics of previous related works on olfactory scents.

Concludingly, there are many opportunities to have olfactory media in messaging application in order to enhance users' engagement and experience while using these applications. In this study, we aimed to measure users' ability to perform a set of tasks when undertaking tasks with MIM (Mobile Instant Messaging) apps. Those tasks were sending a message, reading and replying to an incoming message, deleting a chat, adding a contact, and deleting a contact.

3. Materials and Methods

3.1. Study Experimental Design. Within this experiment, a data recall exercise from actual users interacting with a set of smartphone apps (i.e., a group of MIM apps) has been performed. The key element for this research is the exploration of the potential of olfactory stimuli as enhancer of user's focus while interacting with mobile devices.

Study participants were allocated to one of two groups—an experimental group and a control group. Participants in the former group interacted with the MIM apps whilst experiencing olfactory stimuli, whereas participants in the control group did the same exercises without any such stimuli being emitted.

3.2. Setting. The following instruments should be selected to reproduce the experimental phase of this study:

(i) Room (see Figure 1): an isolated room with a neutral odour has been selected. In order to avoid any kind of bias, the control group participants would not be called in immediately after an experimental group participant (i.e., room with potentially lingering aroma) had concluded all his/hers required tasks. For this experiment, the experimental group participants have been invited after all control group participants concluded their participation.

(ii) Cards with instructions (see Figure 1(e)): set of paper cards with key instructions for the participants, which were to be delivered to the participants after the welcome briefing. Cards include short and explicit information on what it is expected for the experiment.

(iii) Mobile device (see Figure 1(f)): to be used by participants. It will include all the apps to be used in the experiments. Previous to the experiment session with a new participant, included apps should be reconfigured for a clean use by the new participant.

(iv) Webcam (see Figure 1(c)): a standard webcam has been selected. It has been used to record users' interactions and gestures with the mobile device (and the app). It has been attached with a custom hardware to the device itself and connected to the laptop with a standard USB cable.

(v) Heart rate monitor bracelet (see Figure 1(g)): for completeness, QoE should be monitored both using subjective, self-reported, measures, as well as objective ones. Of the latter, the most commonly used are physiological measures [44–49]. In this respect, in our study, we chose to monitor the participant's heart rate. In order to monitor the accompanying signal, a wearable activity tracker was employed. Accordingly, BPM (beats per minute) logs were extracted for each participant at the end of the session. Bracelet logs were cleared prior to each session commencing.

(vi) Laptop (see Figure 1(b)): to be managed by a supervisor. Storage for webcam recordings and heart rate monitor bracelet.

(vii) Aroma dispenser (see Figure 1(d)): the aroma dispenser employed to send the required scents toward the user was an Exhalia Diffuser SBi4. This comprises a controlled fan continuously emitting a rosemary aroma. It was directly connected to a wall plug. The choice of rosemary as an aroma was due to the fact that it has benefic effects on human short-term memory [53,54].

See Figure 2 for an overview of the designed scenario:

3.3. Participants. Eligibility criteria for participants have been designed to be self-reported, at least, as an intermediate smartphone user with any kind of experience with mobile instant messaging apps. No special skills were required from participants.

Participants' source has been direct contact. Selected participants have been determined as postgraduate students. Recruitment has been done within the college environment at Brunel University area (England).

Regarding participants' distribution among groups, the experimental and control groups' allocation was done randomly.

It should be noted that no mention has been made by recruiters about the aromatherapy side of this experiment.

3.4. Variables. The main objective of this research is determining whether olfactory stimuli enhancement user ability and experience of while performing a set of tasks with a set of MIM apps. Those selected tasks, defined as the main tasks on this type of apps [55], are the following (Table 2): sending a message, reading and replying to an incoming message, deleting a chat, adding a contact, and deleting a contact.

Participants in the experimental group were exposed to an aromatherapy dispenser (i.e., rosemary aroma) as a potential effect modifier to measure.

Participants had to complete those tasks over three different MIM apps. These apps, derived from a systematic usability evaluation over MIM apps [55], have been found to

Table 1: Main characteristics of related works.

Study	Main characteristics
Ademoye and Ghinea [29]	Videos with olfactory scents to enhance user performance
Ghinea and Ademoye [25]	Synchronised videos with olfactory scents to enhance user performance
Suzuki et al. [40]	Synchronised videos with olfactory scents to enhance user performance
Miyaura et al. [41]	Olfactory scents to enhance concentration
Ramic-Brkic and Chalmers [42]	Olfactory scents to enhance concentration
Brkic et al. [43]	Olfactory scents to enhance concentration
Harvey et al. [50]	Olfactory scents to enhance visual attention
Stafford et al. [51]	Characterization of olfactory scents (i.e., word associated to a scent)
Xiang et al. [52]	Characterization of olfactory scents (i.e., emotions associated to a scent)
Howell et al. [52]	Olfactory scents to enhance user performance
Kwok et al. [27]	Olfactory scents to enhance learning
Richard et al. [50]	Haptic and olfactory media to enhance learning
Garcia-Ruiz et al. [51]	Olfactory scents to enhance learning
Covaci et al. [34]	Olfactory-enhanced educational games to enhance learning
Alkasasbeh and Ghinea [30]	Olfactory scents to enhance learning

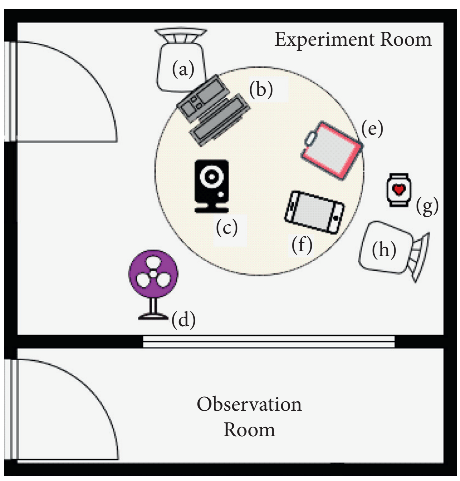


Figure 1: Bird view scheme of experimentation setup, with (a) supervisor position, (b) laptop, (c) recording device (webcam), (d) aroma dispenser, (e) cards with instructions, (f) mobile device, (g) heart rate monitor bracelet, and (h) participant position.

Figure 2: Scenario for the experimentation phase of this study, highlighting (i) aromatherapy dispenser and (ii) hearth rate monitor bracelet.

present good usability results. Selected apps are shown in Table 3 and Figure 3.

3.5. Measurement. One briefing meeting was carried out individually with all participants prior to the experiment session. The goal of this meeting was to tell participants what is expected from them in the experiment's activities, along with paper cards with specific information and data that could be required while the experiment would be carried out (i.e., details on which contact the participants have to interact with within each MIM app).

In summary, any experimental session (either from the experimental or the control group) required selected participants around one hour to complete all required tasks. Rest periods (about five minutes) were applied when each apps' tasks have been completed.

Pilot sessions were also executed to obtain information to re-design, if at all the way the experiment would be carried out. It should be highlighted that extracted pilots' data were not analysed.

3.6. Potential Sources of Bias. It should be highlighted that participants were not informed about their performance results on any of the tasks. The experimental group participants were informed that a rosemary dispenser was plugged in to reduce neutral odour, trying to reduce a possible bias in their performance.

As said before, this study makes use of two group of users, one was the control group (only interacting with MIM apps, no olfactory stimuli applied) and the experimental group (i.e., interacting with MIM apps with the aroma dispenser). We endeavoured to keep the experiment room always with a neutral odour for the control group. Accordingly, on any given day, the control group experiments were carried out first, and then followed by the experimental group ones.

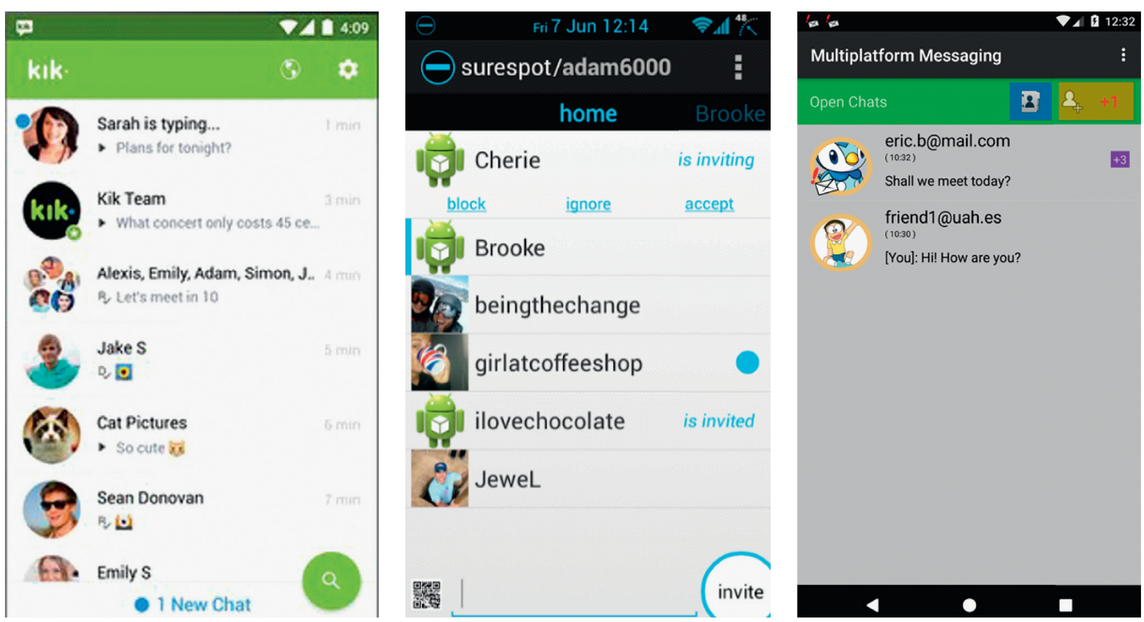
For privacy and ethics purposes, prior to proceeding with any experiment session, verbal consent was obtained to record participants interactions with the mobile device. Participants were informed that their personal information would be anonymised previous to our post-experiment analysis. Furthermore, participants were also informed that video recording would never record their faces, but their hands interacting with the device.

Table 2: Tasks to be completed by participants.

Task	Task details
Sending a message	Participant required to send a message (open text) to a specific given contact.
Reading and replying to an incoming message	The app receives a new incoming message from a specific contact. Participants should open that given chat and answer to the message (open text answer).
Deleting a chat	Delete a specific chat with a specific contact.
Adding a contact	Add a new contact to the platform. Profile details of the contact are provided to the participants.
Deleting a contact	Delete a specific contact. Block is allowed, if delete feature is not present in the app.

Table 3: Details of the MIM apps selected for this study.

MIM app	App details
Kik Messenger [56] (Figure 3(a))	Popular MIM app in USA. Presents an attractive UI aligned with the styles of well-known MIM apps.
Surespot [57] (Figure 3(b))	MIM app focused on providing high levels of security and privacy features.
Multiplatform messaging [58] (Figure 3(c))	MIM app designed to enhance usability features.



(a) (b) (c)

Figure 3: Screens of the selected MIM apps: (a) Kik Messenger. (b) Surespot. (c) Multiplatform Messaging.

3.7. Quantitative Variables. Given that participants were interacting with UIs, the following variables have been measured: time on task, keystrokes, and errors. Additionally, participants wore an electronic bracelet making it possible to use the heart rate as a measured variable. Hence, four variables have been measured for this research:

(i) Time on task: data expressed in seconds, meaning the active time required to complete all tasks.

(ii) Keystrokes: measuring efficiency with the number of interactions required to complete all tasks, based on a KLM (i.e., Keystroke-Level Model) method adapted to mobile interfaces [59].

(iii) Errors: detours from the expected actions, in the form of number of interactions beyond the scope or not related et al.l with the required task path.

(iv) Heart rate: participant's hearth logs during all the experiment session, with data expressed in beats per minute (i.e., BPM).

3.8. Statistical Methods. The study's data consist of scores, within an experimental design (i.e., looking for differences between the aromatherapy and control groups), with independent measures (i.e., previously presented variables) on two groups (i.e., the experimental and control groups).

Following Field and Hole's [60] recommendations, Student's test (t-test) should be applied to parametric data,

Table 4: Characteristics of study participants.

User	Gender	Age	Experience with mobile devices	Time using IM apps/day
u1	Male	35–49	Advanced	0%–25%
u2	Male	18–24	Advanced	25%–50%
u3	Female	25–34	Advanced	25%–50%
u4	Male	25–34	Advanced	25%–50%
u5	Female	35–49	Intermediate	0%–25%
u6	Male	35–49	Expert	25%–50%
u7	Male	35–49	Expert	25%–50%
u8	Male	35–49	Expert	25%–50%
u9	Female	35–49	Advanced	25%–50%
u10	Male	35–49	Advanced	0%–25%
eU1	Female	35–49	Advanced	25%–50%
eU2	Female	25–34	Advanced	50%–75%
eU3	Male	35–49	Advanced	0%–25%
eU4	Female	35–49	Expert	0%–25%
eU5	Female	35–49	Advanced	0%–25%
eU6	Male	25–34	Advanced	25%–50%
eU7	Female	35–49	Advanced	0%–25%
eU8	Female	35–49	Intermediate	0%–25%
eU9	Male	25–34	Advanced	25%–50%
eU10	Male	35–49	Expert	25%–50%

Table 5: Statistical results. Student's *T*-tests applied on time on task, keystrokes, and errors variables. Mann–Whitney test applied on hearth rate variable.

Variable	Statistical results		
Time on task	$M_{\text{control}} = 541.7$, $\text{SD}_{\text{control}} = 252.162$	t (18) = 0.245, $p = 0.809$	$M_{\text{case}} = 517.1$, $\text{SD}_{\text{case}} = 193.243$
Keystrokes	$M_{\text{control}} = 157.6$, $\text{SD}_{\text{control}} = 68.090$	t (18) = 0.311, $p = 0.759$	$M_{\text{case}} = 149.7$, $\text{SD}_{\text{case}} = 42.641$
Errors	$M_{\text{control}} = 8.6$, $\text{SD}_{\text{control}} = 5.700$	t (18) = 0.226, $p = 0.824$	$M_{\text{case}} = 9.1$, $\text{SD}_{\text{case}} = 4.067$
Heart rate		$U = 40$, $p = 0.481$	

while Mann–Whitney test (*U* test) should be applied to nonparametric data.

4. Results

4.1. Participants. This study selected 20 participants, which were randomly divided into two equal-sized groups, namely, the experimental and control groups, as described in the previous section.

The control group (Nc = 10) has seven males and three females, most of them (70%) in the age range of 35–49. More than a half (60%) of the participants have been considered themselves as advanced users with mobile devices, most of them (70%) with a 25%–50% of daily mobile usage dedicated to MIM apps.

The experimental group (Ne = 10) consisted of four males and six females, most of them (70%) in the age range of 35–49 years old. Most of the participants (70%) have been considered themselves as advanced users with mobile devices. Regarding the daily mobile usage dedicated to MIM apps, half of the participants reported 0%–25% of daily usage, and almost a half have reported being in the 25%–50% of daily usage.

Detailed data of participants are shown in Table 4. It is important to highlight that all users, in both the experimental and control groups, declared that they have not previously used any of the analysed apps.

4.2. Main Results. In order to determine statistical test to launch, parametric test and Levene test have been performed over raw data. As a result, all data, except heart rate bpm, presented a parametric distribution. All data satisfied the Levene test (i.e., homogeneous variances). Hence, the Student's *T*-test (*T*-Test) has been performed over time on tasks, keystrokes, and errors, and Mann–Whitney test (*U* Test) has been performed over heart rate data. Table 5 presents the statistical results.

As seen in the previous table, there has not been a significant difference in the scores for the control group and the case group in any of the analysed variables. The results of the analysed variables indicate quite similar results between the participants in the control group and the case group (i.e., participants affected by aromatherapy emitter).

Although, indeed, there are no statistically significant differences between the two groups analysed, some points are worth highlighting if we analyse the values of the distribution of the mean of the variables analysed between the two groups.

First, on the variable "*time on task*", the mean time required is slightly lower in participants influenced by the aromatherapy emitter (as seen in Figure 4). Approximately, it takes on average 25 seconds less to complete the required activities when participants are under the aroma used. It could be said that aromatherapy boosts effectiveness, since the results are more compact (i.e., smaller standard deviation) in the case group ($SD_{case} = 193.24$) than in the control group ($SD_{control} = 252.16$).

Second, regarding the variable "*keystrokes*", the mean number of interactions is practically similar in both groups (as seen in Figure 5). Similarly to the time to complete the required activities, the distribution of keystrokes (i.e., the number of interactions with the device) presents more compact data in the case group ($SD_{case} = 42.64$) than in the control group ($SD_{control} = 68.09$). It could be said that aromatherapy has had a positive effect on the effectiveness of the participants.

Third, on the variable "*errors*" (i.e., number of interactions that are not correct when the participant is trying to complete the required activities), the mean number of errors committed is practically similar in both groups ($Errors_{control\text{-}mean} = 8.6$; $Errors_{case\text{-}mean} = 9.1$). Distribution is shown in Figure 6. Although the results are relatively compact in both groups, the deviation of the data is slightly lower in the participants of the experimental group ($SD_{control} = 5.70$; $SD_{case} = 4.067$). It could be said, therefore, that aromatherapy may help participants to make fewer number of errors.

Finally, a few remarks on the distribution of heart rate data of the participants during the duration of the experiment, as seen in Figure 7. The mean BPM of the control group ($BPM_{mean\text{-}control} = 85.885$) is relatively higher than those that could be measured in the participants who were under the influence of the aromatherapy emitter ($BPM_{mean\text{-}case} = 76.425$). With these results, we could say that, indeed, the effect of aromatherapy is visible in a lower level of pulsations. We can also identify a high number of outliers in the control group data. This dispersion also seems to be solved by the application of aromatherapy. As with the previous variables, it can be observed that the results are more compact in the control group ($SD_{control} = 1.878$) compared to the control group ($SD_{case} = 8.475$).

These results are also visible if we look at the distribution of pulses per application, as shown in Figure 8. The above-mentioned outliers are also applicable to each of the apps (in the control group). Looking at the data, we can see more compact results for the participants in the experimental group. With these data, it could be said that aromatherapy may have a positive effect on increasing users' concentration.

The maximum and minimum pulse values can also be analysed. On the one hand, the mean minimum BPM values are very similar (Figure 9(a)), both in the control group ($BPM\text{-}MIN_{mean\text{-}control} = 62.4$) and in the case group ($BPM\text{-}MIN_{mean\text{-}case} = 61.2$), although the deviation of the data is smaller in the case group ($BPM\text{-}MIN_{SD\text{-}case} = 5.903$) than in the control group ($BPM\text{-}MIN_{SD\text{-}control} = 11.462$). On the other hand, the mean maximum BPM values (Figure 9(b)) that can be detected are higher in the control group ($BPM\text{-}MAX_{mean\text{-}control} = 105.3$) than in the case group ($BPM\text{-}MAX_{mean\text{-}case} = 88$), including a higher data deviation in the experimental group ($BPM\text{-}MAX_{SD\text{-}control} = 36.700$) than in the case group ($BPM\text{-}MAX_{SD\text{-}case} = 9.297$). Taking into account of these data, a positive effect could be deduced with

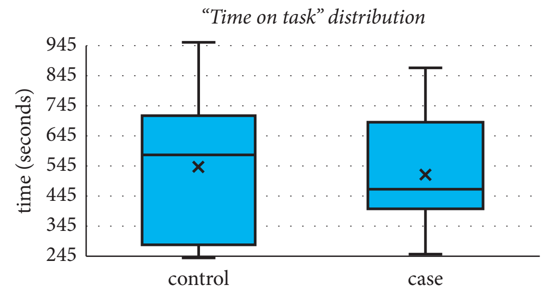


FIGURE 4: "Time on task" distribution.

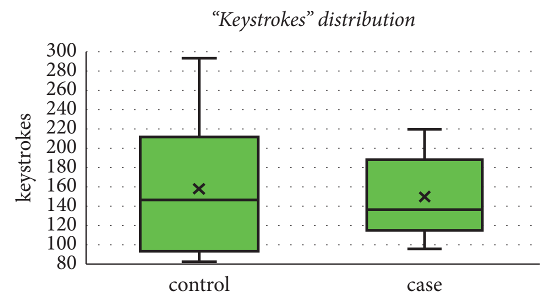


FIGURE 5: "Keystrokes" distribution.

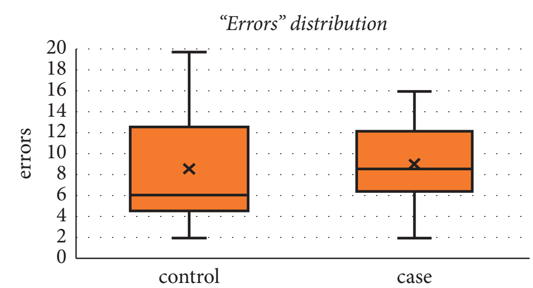


FIGURE 6: "Errors" distribution.

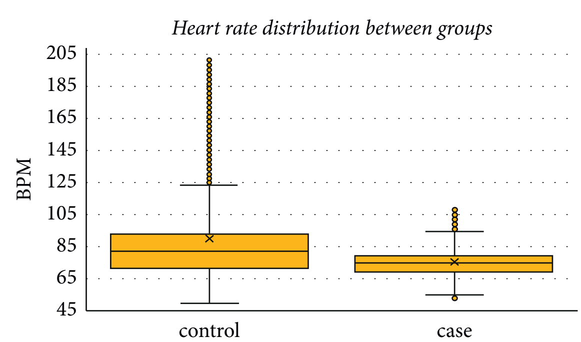


FIGURE 7: Heart rate distribution between groups.

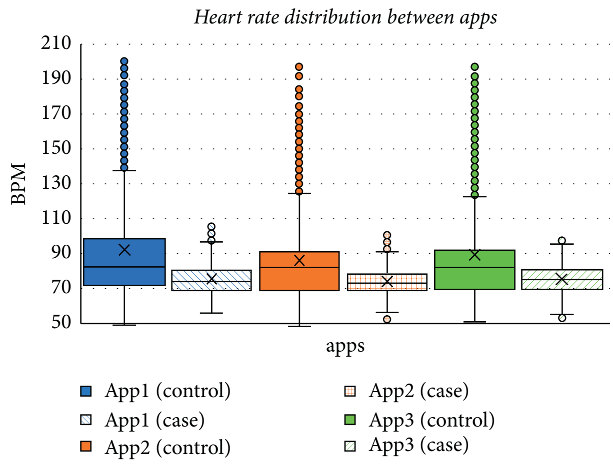


FIGURE 8: Heart rate distribution between apps.

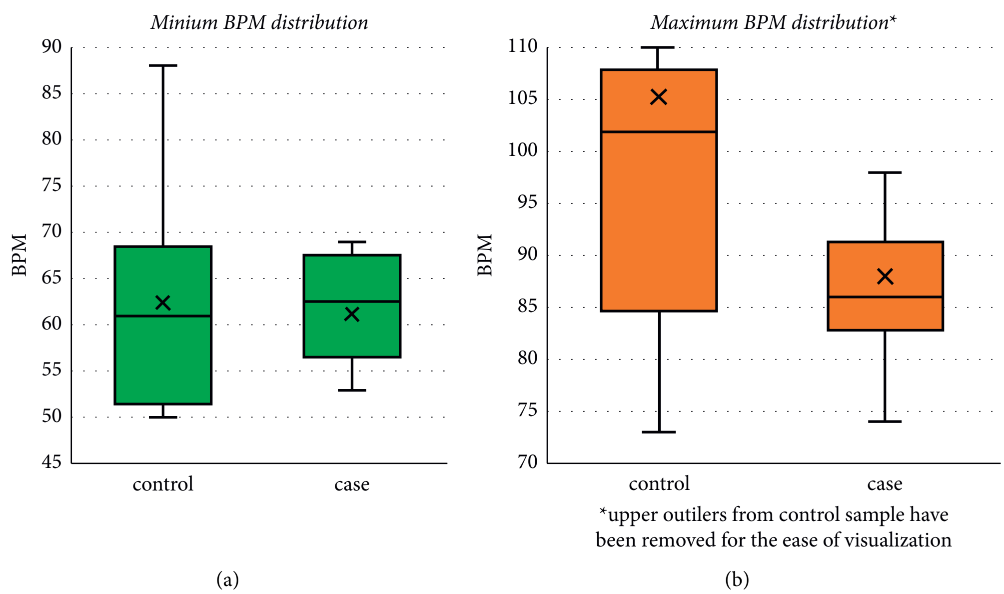


FIGURE 9: BPM distribution: (a) minimum BPM distribution. (b) Maximum BPM distribution.

the application of aromatherapy: reduction of the maximum BPM that a participant can reach.

5. Discussion

5.1. Key Results. These results suggest that olfactory stimuli do not have a clear impact on mobile users QoE when it comes to interaction with MIM apps on a smartphone. At this point, it is difficult to categorize to which degree olfactory stimuli could be attributed to enhance the engagement of users.

Whilst it could be said that olfactory stimuli do not produce a clearly negative effect on the performance of the participant, we think that the effect of such stimuli is, actually, positive but that the sample size is not large enough to detect the differences that we believe should be shown. Indeed, previous work has highlighted the potential that olfaction has in e-learning [24], information recall [29], and word-search [26]. Moreover, we note that our heart rate profiles are in line with those obtained in previous studies [61,62] which indicated that olfactory stimuli have a relaxing and not distractive impact on users' QoE. Concluding, perhaps what our results do show is that olfactory stimuli are not necessarily a panacea in a digital context and that more research should be done on their targeted use. Indeed, the most valuable lesson to take forward is that the very fact that psycho-physical phenomena and effects associated with olfactory perception have been shown to occur in the non-digital world does not automatically mean that these seamlessly translate to the digital realm—again, more research is needed to further explore the applicability of olfactory effects in a digital setting. Last, but certainly not least, it is entirely plausible that such work will uncover effects which have their sole manifestation(s) in the digital worlds—lending even more impetus to such research endeavours.

5.2. Limitations. The main limitation of this approach may be seen in the reduced number of participants in both groups. As described previously, we were able to recruit ten participants per group. This may be the reason why we have not able to discover better efficiency markers of olfactory stimuli.

5.3. Interpretation. After considering proposed objectives, limitations, and results, we could say that our findings support the idea that what it is, indeed, true is that olfactory stimuli are neither an impediment to mobile users' engagement nor does it hinder the operation of mobile apps.

In fact, we could say that aromatherapy seems to have a positively effect on the users' performance with a smartphone (i.e., slightly lower times and number of interactions to complete required tasks, on average) and a better reaction towards the smartphone operation (i.e., slightly reduced cardiac rhythm, on average, and more stabilized cardiac activity).

6. Conclusions

This paper has presented an experimental study on olfactory stimuli effects on mobile users' performance within activities on mobile instant messaging apps. This paper, and its findings, could be seen as a preliminary validation on this field, aiming to prove that olfactory stimuli could be beneficial to enhance mobile user engagement.

All participants interacted with a smartphone and a set of mobile instant messaging applications. The main objective of the participants was to perform a series of tasks on these apps: send a message, read and reply to an incoming message, delete a conversation, add a contact, and delete a contact. In addition, the participants selected for the experimental group performed these activities with the presence of an aromatherapy emitter in the same room, emitting a rosemary aroma.

Whilst there have been no statistically significant differences between studied groups (i.e., case and control groups), our results are encouraging, nonetheless. Results have shown a slightly enhancement on performance and cardiac activity of those participants under the influence of aromatherapy stimuli (in this case, a rosemary emitter).

It has been noticed that with the analysed performance variables "*time on task*" (i.e., time required to complete activities) or "*keystrokes*" (i.e., number of interactions to complete activities), average values for the experimental group are lower. In other words, it could be concluded that the use of aromatherapy techniques has a positive effect on the performance of smartphone users.

Likewise, cardiac rhythms are, on average, lower and more stable in the participants of the experimental group. In addition, maximum BPMs measured are also lower in the aromatherapy participants. It could also be concluded that the use of olfactory stimuli has a quite positive effect on the cardiac pulse of smartphone users. As future work, more research experiments should further develop and enhance these initial findings with experiments comprising a larger number of participants. Whilst mulsemedia is not a panacea for task and performance enhancement in a digital context, more work should be undertaken exploring to delineate appropriate use cases for its utilisation. More diverse tasks incorporating mulsemedia should be explored on a variety of platforms, ranging from traditional desktop to mobile and to VR/AR/XR. Only by so doing, can a better understanding of what the implication of use are and provide confirmatory evidence of the benefits of mulsemedia-based interaction to all stakeholders involved.

Data Availability

The data used to support the findings of this study are included within the article, and raw data set is provided as supplementary material.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Supplementary Materials

Control and experimental raw data sets are provided as additional part of the manuscript. (*Supplementary Materials*)

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