Designing a mobile persuasive application to encourage reduction of users' exposure to cell phone RF emissions

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Abstract. The International Agency for Research on Cancer classifies radiofrequency (RF) electromagnetic emissions of cell phones as possibly carcinogenic to humans [1] and suggests the use of hands-free devices such as earphones to reduce direct exposure of the brain to such emissions. In this paper, we present the design of a mobile application that exploits persuasive principles to encourage the use of earphones during cell phone calls. We propose different notifications and visualizations aimed at informing the user about her behavior with respect to earphone use and discuss the results of a user study that was aimed at investigating aspects such as understandability, emotional impact, and perceived usefulness of the proposed solutions. Results of the study are used to inform the design of the application. To the best of our knowledge, this is the first investigation of persuasive technologies applied to the reduction of user's exposure to cell phone RF emissions.

Keywords: mobile persuasion, mobile phones, behavior change, health, RF emissions, earphones

1 Introduction

Today, the positive effects of the availability of cell phones on our quality of life are undeniable. However, there is also concern about the potential negative impact of cell phone use on health even if the subject is controversial. In particular, currently available research has not provided complete evidence of a relationship between cell phone use and adverse health effects. However, pending more definitive answers, in 2012 the International Agency for Research on Cancer (IARC) changed the classification of radiofrequency (RF) electromagnetic emissions of mobile phones from level 4 (probably non-carcinogenic) to level 2B (possibly carcinogenic) [1]. To reduce user's exposure to radiofrequency energy, organizations such as the IARC, the Federal Communication Commission, and the Food and Drug Administration recommend

pragmatic measures such as using cell phones only for shorter conversations and using hands-free devices which place more distance between the phone and users' head.

In this work, we explore persuasive technology as a way to foster awareness on the possible risk of RF emissions and recommend the use of earphones. In recent years, persuasion principles have been applied to the design of mobile applications aimed at such diverse goals as increasing user's physical activity [2] or encouraging the use of green transportation [3]. In our case, the cell phone is the ideal medium through which to convey the considered persuasive message. First, the cell phone is directly related to the target behavior, hence making it possible to convey messages at the most appropriate time. Second, users can be often reminded that they are trying to change their behavior since they take cell phones with them anytime, anywhere. Third, the cell phone is typically a personal object, not shared with others, which makes it ideal as a way to convey health-related messages.

In the paper, we illustrate the design of BrainSaver, a mobile application for Android smartphones that monitors call behavior and gives feedback about how the user is behaving with respect to the use of earphones. To determine the most appropriate stimuli to help the user improve her behavior while avoiding to annoy her with invasive and unsuitable messages, we created different notifications and visualizations based on persuasive principles and evaluated their effect with a user study. The study focused on aspects such as understandability of the messages, emotional impact of the visualizations, and perceived usefulness of the notifications.

2 Related Work

Some persuasive mobile applications have recently used the phone screen wallpaper to provide mobile users with feedback about specific behaviors, mapping them into metaphoric visualizations. In UbiFit Garden [2], the user is persuaded to maintain a certain level of physical activity through a wallpaper that displays weekly progress in the form of flowers (representing different performed activities) and butterflies (representing achieved goals). UbiGreen [3] was instead designed to make the user more conscious about her consumption of CO2 through a wallpaper that displays a tree or a polar scenario with bears and icebergs whose state depends on the level of CO2 consumption. In EcoIsland [4], users are mapped into virtual characters on an island, and positive behaviors are rewarded by allowing users to decorate their environment, while negative behaviors lead to flooding of the island. While some studies suggest to use only positive reinforcement to prevent users to feel frustrated when they do not achieve their goals [5], the evaluation of EcoIsland and UbiGreen pointed out that people were encouraged also by the negative feedback received by seeing the negative consequences of their actions on the visualization.

Changes in the wallpaper have the dual function of giving the user feedback on her actions and to remind her that she is trying to change her behavior since often this is not her main thought [6]. The reminder function is crucial to convey the message at the most appropriate time, i.e., immediately preceding or following the triggering of the unwanted behavior [7]. The message must also be presented in the most aestheti-

cally pleasing and less intrusive way [8]. Moreover, since the message pertains to the private life of an individual, it must be presented in an abstract way so that other people who happen to see the user's phone could not easily understand the meaning of the visualization.

Besides providing feedback through the wallpaper visualization, the mobile application should build trust in the recorded data from which the visualization is derived. This can be achieved both by showing the user a history of how she behaved in the past in a truthful but neutral way, and also by giving the possibility to change behavior data if the application cannot determine data correctness [3][5][7]. To keep the user involved, the application can include an element of fun [9] or aim at establishing an emotional bond with the visualization, e.g. using a virtual animal whose fate is determined by user's behavior [3][10].

3 Considered visualizations

In line with [2,3,4], we propose to use the phone wallpaper as the main way to provide users with feedback about their behavior. More specifically, the wallpaper should be updated each time the user makes or receives a call, based on whether earphones were used or not. To investigate different design choices, we created two wallpapers based on two different subjects, a cartoon dog and a skeleton. The cartoon dog was inspired by the use of virtual animals in the persuasive technology literature as a way to establish an empathic connection with the user [3][10]. The other character was aimed at testing the effect of a less cartoony approach that did not directly show emotions. It was introduced because a first informal test of the cartoon dog indicated that male acceptability of a "cute" emotional virtual character as phone wallpaper could be low. Starting from an initial neutral image, we designed 10 negative variants and 10 positive variants of the basic image (Fig 1). In the skeleton wallpaper, negative variants show a brain in the skull that progressively becomes more visible by turning red (simulating heating), while the positive variants show more and more

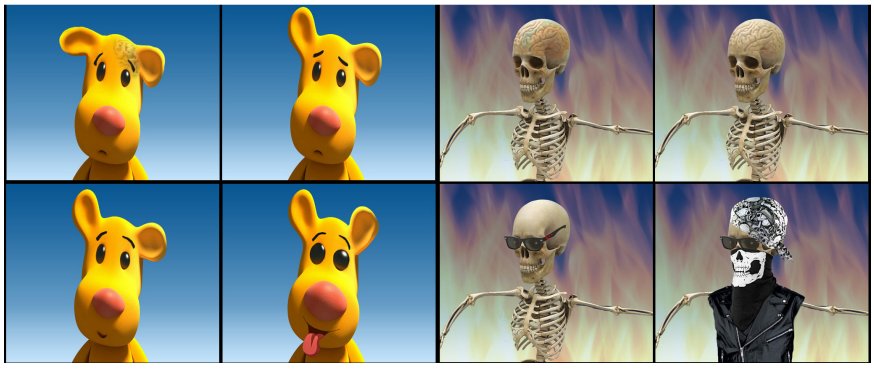

Fig. 1. A sample of images from the dog and skeleton wallpaper progressions.

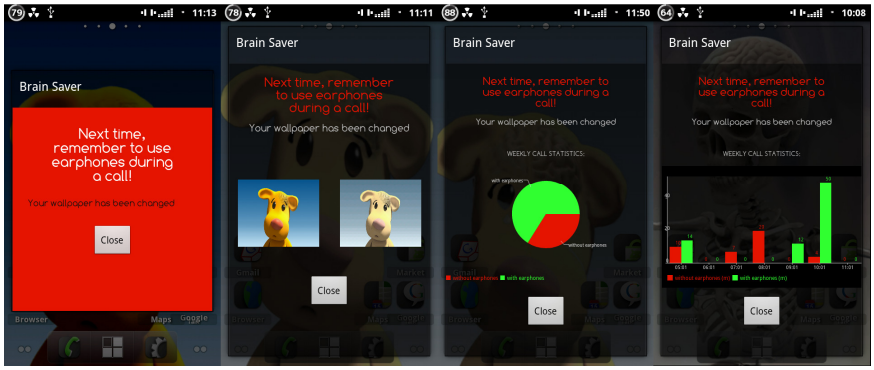

Fig. 2. From left to right, the text, pre-post-call, pie chart, and bar chart notifications.

cloth accessories being added to the character. In the dog wallpaper, the animal becomes sadder in the negative variants while it becomes happier in the positive variants. To keep consistency with the skeleton design, and always remind the user of the goals of the application, the state of the brain is clearly shown in the negative levels of the dog wallpaper.

Unlike the previously mentioned mobile persuasive applications, which rely only on updating the wallpaper to convey their message, we also designed four alternative notifications to inform the user about the wallpaper change right after the end of a call without earphones (Fig. 2).

- The text-only notification (Fig. 2 upper left) displays a simple message reminding the user to use earphones the next time she makes or receives a call. The message uses an eye-catching red background which seems to be appropriate to convey important messages related to health [11].
- The pre-post-call notification (Fig. 2 upper right) displays the same message used in the text notification, and also shows a comparison of the state of the wallpaper before and after the last call. This notification provides a direct connection to the wallpaper, making users aware of how it changed as a consequence of the last call.
- The pie chart notification (Fig. 2 lower left) shows a graph summarizing the amount of calls with and without earphones in the last week. This notification allows the user to have a more global view of her behavior, which should encourage her to change it if considered negative.
- The bar chart notification (Fig. 2 lower right) shows a graph of the number of minutes users spent with and without earphones during calls for each day of the last week. In this way, the user can see trends in her behavior, which can serve as positive reinforcement if the data shows some progress over time.

None of the proposed notifications (as well as the wallpapers) provides quantitative data about the last call (e.g., how long it lasted) but only a qualitative indication of user's behavior during such call (or in the past days). This is done to avoid giving the

impression that the application is intruding too much into users' conversations and private life.

We designed the wallpapers and the notifications based on the following persuasive principles and techniques:

- *Reminder*: since users tend to forget that they are pursuing a specific objective, a message should be shown each time they should remember to use earphones. Also, the wallpaper should be changed to make the user aware of the goal even when she is doing other actions with the cell phone [6][12].
- *Feedback*: the user should be given immediate feedback about the action she has just performed. This is important to make the user immediately aware of the consequences of her actions and also to keep the user aware that the application is accurately monitoring her actions, thus increasing its credibility [4][7][13].
- *History/Trend*: the user should be offered the possibility to review the history and trends related to the last week of use of the application, to allow her to better monitor her behavior over time [12].
- *Positive/Negative reinforcement*: changing the wallpaper is a way to manage both positive and negative reinforcement with respect to user's actions, following an operant conditioning paradigm [7].
- *Empathy*: one of the two wallpapers uses a cartoon dog to exploit the possible empathic connection that could be established between the user and the virtual animal, as in [3][10].
- *Interoception*: visualizing the state of the brain in the negative sequences of wallpapers aims to give users a sense of the physiological condition of the body (interoception), making them perceive the possible changes in their brain due to the lack of earphones use. This idea was inspired by recent work on persuasion which is exploiting biomarkers (e.g. obtained through actual medical imaging of parts of the patient body [14]) to encourage health behavior change.
- *Fun and Engagement*: to maintain user's interest, the state of the virtual characters changes in a fun and engaging way [9].

4 User study

To evaluate the effects of the considered visualizations on users, we carried out a lab study that investigated wallpaper preference and understandability, emotional impact of characters, and usability of post-call notifications. Wallpaper understandability was evaluated using card sorting: users were provided with paper cards depicting each wallpaper variant and were asked to separate negative variants from positive variants and then order all variants from the most negative to the most positive. Wallpaper preference, emotional impact of characters, and usability of post-call notifications were instead evaluated by showing users mock-up versions of the wallpapers and notifications on an actual mobile device and asking users to fill questionnaires for each considered aspect.

4.1 Participants

Sixteen users (9 male, 7 female) participated in the study. Their age ranged from 20 to 28 (M=26, SD=2.3). The average number of daily cell phone calls per user was 1.79 (SD=1.32), 50% of users made more than one call per day and 12.5% made more than 3 calls. Half of the users said they never use earphones during calls, mainly because they consider earphones uncomfortable or do not have them at hand when needed; 37.5% of the users claimed to use earphones only while driving or when needing their hands free.

4.2 Procedure

The study did not involve coercion or deceit and did respect applicable professional code of conduct. Users first filled a questionnaire to collect demographic as well as phone call statistics and earphone usage data. Participants were then briefed about the nature of the study. Then, they carried out the following 5 tasks:

- Grouping: users were handed two decks of paper cards depicting all wallpaper variants (one deck for each wallpaper) and asked to separate positively and negatively perceived variants. Half users started with the dog and half with the skeleton variants. The order of cards for each wallpaper was randomly generated for each user to avoid possible order effects. At the end of the task, users were asked to explain the criteria they used in separating variants. As a measure of user's success, we noted the number of errors users made compared to the correct grouping of variants.
- Ordering: users were handed two decks of cards (with a randomly generated order) and asked to order all variants from the most negative to the most positive for each wallpaper. As in the grouping task, at the end users explained the criteria they had used to complete the assignment. In this task, we measured the distance between positions indicated by users and the correct positions of variants in the card order.
- Preference: users were shown the two neutral conditions of the wallpapers as images on an actual mobile device (Android smartphone with 4.3" screen) and were asked to express their preference for the wallpapers on a 5-levels Likert scale (1=not at all; 5=very much). Users could move between the two images by a simple swiping gesture on the screen.
- Emotional impact: users were shown the two most extreme variants (-10 and 10) of the wallpapers on an actual mobile device and were asked to fill a questionnaire aimed at determining what emotions users felt while looking at the images. Questions were statements of the form "This character conveys a sense of happiness" and users could answer on a 5-levels Likert scale (1=not at all; 5=very much). We specifically considered the following set of emotions derived from the relevant literature on emotion measurement [15]: happiness, enthusiasm, enjoyment, nervousness, anger, fear, sadness, shame, and guilt.
- Post-call notifications: users were shown each of the four post-call notifications on an actual mobile device and were asked to fill a questionnaire containing statements about the clarity, effectiveness, aesthetic pleasantness, and usefulness of

the notifications. An example statement is “This notification is clear”. Users could answer on the same 5-levels Likert scale used for emotional impact.

4.3 Results

For the grouping task, the Wilkoxon signed-rank test did not reveal a statistically significant difference in the number of errors for the two wallpapers ($p=0.07$, $W=-36$). Means are shown in Fig. 3 (left). However, users tended to consistently make more errors with the skeleton wallpaper and some of the users perceived all variants of the skeleton wallpaper to be negative, commenting that the skeleton did not convey to them any positive meaning.

For the ordering task, the Wilkoxon signed-rank test did not reveal any statistically significant differences between the means of the number of errors for the two wallpapers ($p=0.36$, $W=-19$). Means are shown in Fig. 3 (center). However, users made more serious errors with the skeleton wallpaper compared to the dog wallpaper, where errors typically consisted in inverting two adjacent variants.

The Wilkoxon signed-rank test revealed a statistically significant effect for subjective preference ($p<0.01$, $W=67$), with users highly preferring the dog wallpaper to the skeleton wallpaper (Fig. 3 right).

For the emotional impact task, Figure 4 shows mean ratings for both positive emotions (happiness, enthusiasm, enjoyment) and negative emotions (nervousness, anger, fear, sadness, shame, and guilt). Friedman’s test revealed a significant effect for happiness ($p<0.0001$, $F=43.96$), enthusiasm ($p<0.0001$, $F=42.07$), enjoyment ($p<0.0001$, $F=42.70$), guilt ($p<0.0001$, $F=34.17$), sadness ($p<0.0001$, $F=34.61$), and fear ($p<0.0001$, $F=20.64$). For happiness, enthusiasm, and enjoyment Dunn’s post-hoc test pointed out a statistically significant difference ($p<0.01$) between both negative variants (level -10) and both positive variants (level 10) of wallpapers, with positive variants conveying a higher level of happiness, enthusiasm, or enjoyment. The ratings for nervousness, anger, fear, and shame were very low regardless of wallpaper variant. For guilt, Dunn’s test revealed a statistically significant difference ($p<0.01$) between the negative variant of the dog wallpaper and both positive variants, with a higher score for the negative variant. For sadness, Dunn’s test revealed a statistically significant difference ($p<0.01$) between the negative variant of the dog wallpaper and

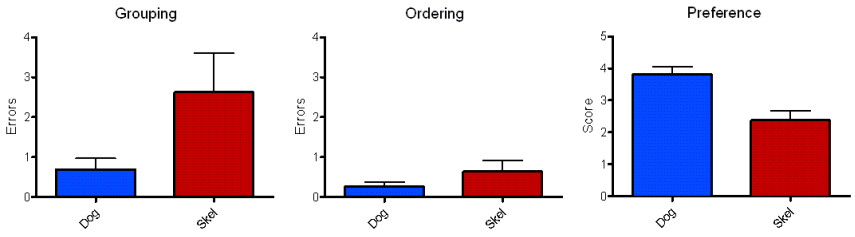

Fig. 3. Mean number of errors (with standard error bars) in the grouping (left) and ordering tasks (center) and mean preference (right) for the two wallpapers.

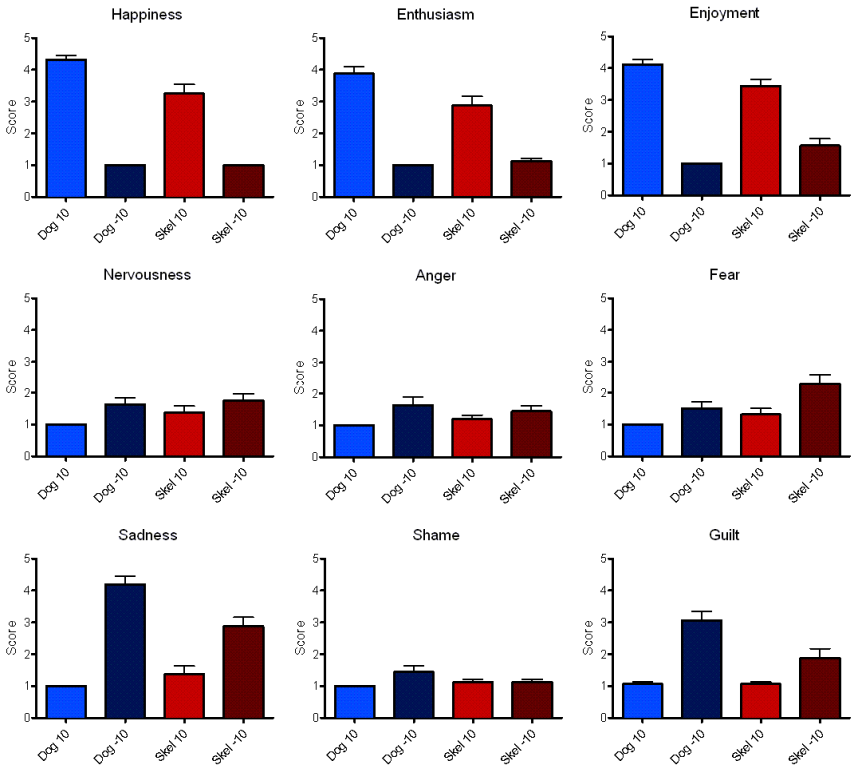

Fig. 4. Mean happiness, enthusiasm, enjoyment, nervousness, anger, fear, sadness, shame, and guilt ratings for variants -10 and 10 of the two wallpapers.

both positive variants, and between the negative variant of the skeleton wallpaper and the positive variant of the dog wallpaper, with a higher score for the negative variants. For fear, Dunn's test pointed out a statistically significant difference ($p<0.01$) between the negative variant of the skeleton wallpaper and the positive variant of the dog wallpaper, with a higher score for the negative variant.

Figure 5 shows means of user ratings for post-call notifications. Friedman's test pointed out a significant effect for clarity ($p<0.05$, $F=10.07$) and aesthetic pleasantness ($p<0.001$, $F=18.32$). Dunn's post-hoc test revealed that the text-only notification was perceived to be clearer than the bar chart notification ($p<0.01$) and that the pre-post notification was the most aesthetically pleasing ($p<0.01$).

5 Discussion

The higher preference for the dog wallpaper compared to the skeleton wallpaper might be due to the stronger empathic connection users seem to establish with a

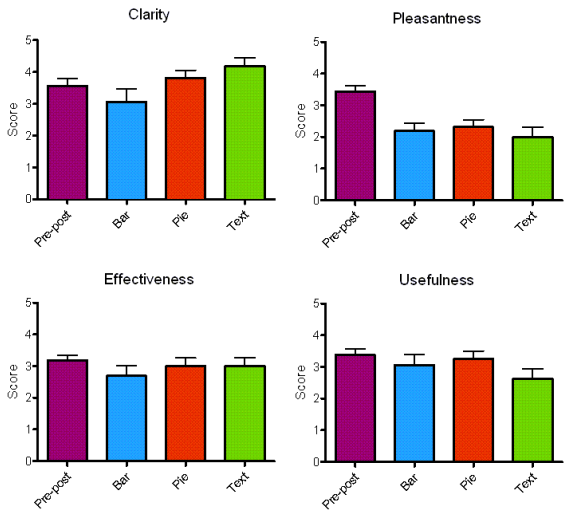

Fig. 5. Mean clarity, aesthetic pleasantness, effectiveness, and usefulness ratings for the post-call notifications.

virtual animal compared to other subjects as shown in other work in the literature [3][10]. It is interesting to note that females rated the skeleton wallpaper higher than males. On one side, this is possibly a general consequence of female tendency to give higher ratings in self-report scales dealing with emotions and preferences [16]. On the other side, males could have disliked the addition of cloth accessories to the skeleton in the positive variants of the wallpaper.

While we found no significant difference between the two wallpapers in terms of their understandability, some of the users had much more difficulty in interpreting the skeleton wallpaper than the dog wallpaper. In particular, there were users who considered all skeleton variants as negative. Additionally, from user's comments after the ordering task, we found that users tended to compare skeleton variants (especially in the positive group) based on a purely logical criteria, i.e., the number of accessories displayed on the character, while dog variants where compared based on more complex criteria, i.e., by considering the emotions displayed by the virtual character. These results, coupled with the higher global preference for the dog wallpaper, make us conclude that the skeleton wallpaper is less suitable than the dog wallpaper for our purposes.

The analysis of the emotional impact of wallpapers revealed that users associated positive wallpaper variants to positive emotions and negative wallpaper variants to negative emotions. However, while both types of positive wallpaper variants showed a connection to all the positive emotions we considered (happiness, enthusiasm, enjoyment), the emotional response to negative wallpaper variants was much more varied. Ratings for nervousness, anger, and shame were very low for both types of wallpaper variants. This can be considered a positive outcome since our wallpapers

were not designed to induce this type of negative emotions, which could be counterproductive in an application aimed at behavior change and lead to abandon the application. Fear ratings were also very low and the only statistically significant difference we found was across wallpapers (i.e., between the negative skeleton variant and the positive dog variant), with no substantial variation in fear within the same wallpaper sequence. The negative variant of the dog wallpaper caused a high level of sadness and guilt compared to the positive variants of both wallpapers. This might be positive for the persuasive application since it might push people to use earphones just to improve the dog condition, making the virtual character happier. We did not find a similar effect for the negative variant of the skeleton wallpaper. This might be due to users feeling a limited (if any) emotional connection to the skeleton wallpaper. It should also be noted that, except for fear, user's emotional response to the dog wallpaper was always higher than the response to the skeleton wallpaper. Again, this might be due to a stronger empathic connection with the virtual animal.

The comparison among post-call notifications did not reveal a clear winner. The text-only notification reached a better score in terms of clarity of presentation, even if the difference was statistically significant only compared to the bar chart notification. Probably, this was a consequence of the limited amount of information available in the text-only notification, which made understanding easier. The pre-post-call notification was found to be the most aesthetically pleasing, with all three other notifications reaching a very low score on this aspect. In particular, users did not like the graphical complexity of the graph-based notifications and the graphical simplicity of the text-only visualization. The pre-post notification also reached a better score in terms of perceived effectiveness and usefulness even if there were no significant differences with the other notifications and, in general, all notifications obtained an average score on these aspects.

Overall, from these results we can draw the following conclusions and implications for the design of the persuasive application:

- The skeleton wallpaper does not seem to provide any significant advantage over the dog wallpaper. Inclusion of the dog wallpaper might instead lead to better user acceptance of the persuasive application and stronger emotional connection with the virtual character, thus possibly producing a more engaging and effective experience.
- Users can correctly understand the positivity/negativity level of proposed wallpaper variants. Moreover, they associate positive emotions to the positive variants and negative emotions to the negative variants. This is especially true for the dog wallpaper, whose design seems thus appropriate to provide positive/negative reinforcement in a persuasive application.
- Since aesthetics play an increasing role in the acceptance of current persuasive applications, the pre-post-call notification seems the most appropriate for inclusion in the application. Yet, a more thorough longitudinal investigation would be needed to better understand its impact in terms of effectiveness. Statistics on earphone usage should be displayed only on user request.

6 Final application

Based on the results of the user study, we implemented BrainSaver as an Android application that makes use of the dog wallpaper and pre-post-call notification. The application constantly monitors user's call activity, identifying whether the user has earphones connected whenever she makes or receives a call.

The application operates in different ways based on earphone use and length of calls. If a call lasts less than 20 seconds, the application does not take any specific action. Bothering the user with some persuasive message after these calls would likely be perceived as overly intrusive and annoying, reducing user's willingness to use the application and possibly producing psychological reactance. Moreover, studies in the literature show that the temperature of the tissues which are closest to the cell phone during a call increases only after prolonged calls. If a call lasts more than 20 seconds and the user does not use earphones, the application takes the following actions at the end of the call: (i) the image preceding the currently used one in the wallpaper sequence is selected as base image for the wallpaper; (ii) the wallpaper is changed, using the output of step (i) as image; (iii) the user is notified of the changes to the wallpaper and reminded to use earphones, using the pre-post-call notification presented above. If a call lasts more than 20 seconds and the user uses earphones, the application takes the following actions at the end of the call: (i) the image following the currently used one in the wallpaper sequence is selected as base image for the wallpaper; (ii) the wallpaper is changed, using the image selected at step (i). Statistics on earphone use can be requested at any time by accessing the application options through the notification area.

Like other mobile persuasive applications [3], BrainSaver resets the wallpaper to its initial condition (neutral image) at the beginning of a new week. This is to give a higher sense of progression (positive or negative) in those cases in which the user is stuck at the maximum positive or negative level during the week (because of several consecutive calls with or without earphones, respectively).

7 Conclusions and future work

To the best of our knowledge, our research is the first to propose a mobile persuasive application to encourage safe and healthy behaviors with respect to cell phone RF exposure. The paper has illustrated in detail the design of the mobile application, motivating the different decisions taken and the novel combination of persuasive techniques that range from classical solutions (such as reminders and behavior statistics) to more advanced ones (such as data visualization and encouragement of empathy and interoception through specific visualizations). The user study we carried out provided useful information about the appropriateness of different design choices. We are now planning an extensive longitudinal study, recruiting participants to get data on the regular use of BrainSaver. We will also distribute the application to the public, through Google Play, to collect data on usage and acceptability of the application from larger samples.

8 Acknowledgements

Valeria Marcon greatly helped in the development and evaluation of the prototype.

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