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I am Calm: Towards a Psychoneurological Evaluation of ABC Ringtones

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Abstract. Anthropology-Based Computing (ABC) suggests that socio-cultural, neurological, and physiological parameters of normal human interaction with the world can be applied to current technology in order to improve Human-Computer Interaction (HCI) [1]. To challenge this theory, we hypothesized smartphone ringtones that could be targeted to specific people in a manner that would inform them without disturbing their work or the work of others. In this paper we report the quantitative data from the first formal trials of these 'ABC ringtones'. Beta Wave activity patterns were recorded in the brains of 10 participants exposed to 5 different ringtones at three different volumes while they were focused on performing a typing test in a noisy environment. Our preliminary findings seem to show that the ABC ringtones - at a volume too low to be consciously heard - triggered a response in the pre-attentive part of the brain, and that the embedded information was transferred to the attentive part of the brain by an internal mechanism that did not disrupt the work being done in the typing task. We propose that these results provide preliminary evidence for the ABC model of HCI and its explanation of the centering mechanism that is requisite if Peripheral Interaction [2] is to be applied in changing Ubiquitous Computing [3, 4, 5, 6] into Calm Technology [7].

Keywords: Anthropology-Based Computing (ABC), Calm Technology, Cocktail Party Effect, HCI, Human Factors, Qualitative Data Collection, Ringtones, Safety, System Usability Scale, Peripheral Interaction, Ambient Awareness, Audio.

1 Introduction

More than twenty years ago, Mark Weiser predicted that humanity was headed towards an Era of Ubiquitous Computing; a time when miniaturized electronics would allow previously impossible networks of embedded systems to integrate computerized controls into the basic technology that surrounds us in our daily lives [3]. We now live in the world that he foresaw, a world in which our direct use of one computer involves also using countless other computers without any conscious awareness from the side of the user of doing so. For example, when using one's computer for a simple keyword search, we are aware of the computer and of the software interface, but ignorant of the multitudinous computers involved in running the search or maintaining the database. Though we do not, as users, consider this, it is a truism that using a computer requires a human to adapt her behavior to the needs of the system. Weiser predicted that, in an age that involves constant interaction with countless visible and invisible computers [4], humans would need to be spared from the stress involved in adapting and responding to the demands of all of these systems [5]. Weiser's proposed cure for this predicted stress was a re-design of the basic principles of how humans and computers interact [6]. He called this human-centered re-design "Calm Technology" (CT) [7], and described it as technology designed to be used in the same way that humans interact with information and artifacts in everyday life. As he put it, such "Calm" interaction "engages both the center and the periphery of our attention, and in fact moves back and forth between the two" [7, p.79].

There are currently many interpretations and a few manifestations of CT. Ishii et al.'s *tangible bits* are an attempt to apply the idea that we do not need to adapt our behavior to computer-centered input devices [8]. Streitz and Nixon's principle of the *disappearing computer* [9] champions the idea that a physical interface need not be at the center of our attention. A careful reading of Weiser's original papers [6, 7] points towards a fundamentally different understanding of CT, based on identifying and applying evolutionary, socio-cultural, biomechanical and neurological factors. This *Anthropology-Based Computing* (ABC) [1, 10] is the idea that the way to apply the principles of CT to human computer interaction (HCI) is not to focus on moving HCI input devices from the computer workspace into the real world as suggested by Ishii et al., [8], nor to focus on making interfaces disappear altogether, as argued by Streitz and Nixon [9]. Rather, the way to bring about CT is to design interactions based on how humans naturally perceive, process and produce information. The first suggestion of this focused on our most ubiquitous and personal computers – our portable telephones [11].

To further explore the notion of Anthropology-Based Computing, this paper presents a study on 'ABC ringtones': a method of customizing a ringtone based on the way we are naturally 'primed' for familiar and personally relevant sounds and words. These ABC ringtones give immediate information about the identities of both the caller and the recipient using the recipient's own names and voices of loved ones as ringtones. We hypothesize such ringtones to be perceived at a pre-attentive level of awareness. As such, users might be enabled to clearly recognize that their phone is ringing without disturbing (and, potentially, without even alerting) other people who are nearby. In this paper we report on the quantitative data from an experiment in which 10 participants were subjected to ABC ringtones while performing a separate complex cognitive task in a noisy environment. During this experiment, we recorded Beta Wave activity patterns at five brain locations to gain preliminary insight in the potential pre-attentive perception of ABC ringtones.

2 Related Work

The underlying goal of the experiment reported in this paper was to demonstrate that the ABC approach makes it possible to *encalm* a currently ubiquitous technology as per Weiser's call [7]. The idea that the ringtone can be *encalmed* is based on a well-documented oddity of human perception, which psychologists call *the Cocktail Party Effect* [13].

2.1 The Cocktail Party Effect

When you are carrying on a conversation in a crowded and noisy area (e.g. a cocktail party) in which many other people are carrying on many other conversations - each about as loud as your own - you can still focus on the words of the person talking to you and ignore almost all of the rest of the noise. The human brain's natural ability to recognize and attend to some sounds as words, while filtering out the rest of the sounds and relegating them to the periphery of our attention, was first described by Cherry in 1953 [13]. In 1959, Moray offered an affective advance by pointing out that high-valence words (e.g. one's own name) and sounds (e.g. the voice of a loved one), slip through that filter [14]. The 'cocktail party effect' has rarely been applied to technology designed to communicate with us aurally in day-to-day situations [15], despite the fact that our natural on-line auditory filtering process cannot currently be equaled by computerized systems [16].

Golumbic et al. uncovered a neurological mechanism that may be behind part of the cocktail party effect in a study on volunteers awaiting surgery for epilepsy [17]. In preparation for the surgery, these people had been fitted with networks of electrodes directly on their brains. This provided a unique opportunity to measure brain activity directly. Researchers showed these volunteers videos of two people simultaneously telling separate stories. The participants were asked to try and focus only on one stream of conversation. The areas of the brain responsible for processing sound responded to both voices. The parts of the brain that deal with language responded only to the story on which the listener was focused.

Similar surface EEG measurements have been used to measure brain activity related to auditory perception and the cocktail party effect. One study revealed that brain responses occurring at 200 ms after stimulus onset may reflect the selective attention mechanisms involved [18]. Powers et al. conducted a pilot study on the ability to detect liminal and subliminal sounds with EEG [12]. While their sample size prohibits statistical validation of their claims, they do succeed in raising the issue of separately locating conscious and unconscious perception.

The primary difference between subliminal processing and peripheral interaction is the question of centering. The ability to pre-attentively select peripheral information to focus on (making the subliminal liminal), as happens in the cocktail party effect has a corollary: the ability to relegate signal back to the domain of noise for continued peripheral monitoring (making the liminal subliminal).

2.2 Peripheral Interaction

Many researchers have explored the concept that digital information could be presented such that it can be perceived in the periphery of attention [19], and move between the periphery and center when required. A variety of terms have been used, including ‘calm technology’ [7], ‘peripheral displays’ [20], ‘ambient information systems’ [21], and ‘ambient media’ [22]. An early example of Calm Technology is Natalie Jeremijenko’s ‘Dangling String’(as described by Weiser and Brown [7]): “an 8-foot piece of plastic spaghetti” hanging from a hidden motor in a hallway ceiling. Network activity caused a perterbation in the motor and made the string twitch in a manner easily but subtly visible to workers in the surounding offices. ‘Water lamp’ [23] is an ambient media design intended to promote a feeling of connectedness by showing the heartbeat of a significant other through shadows of water ripples on the ceiling. To a similar end, ‘Motion Monitor’ [24] displays subtly-changing colored light in order to represent movements at a remote location.

Others have explored the use of peripheral ‘auditory displays’ [25]. ‘Audio Aura’ [26], for example, uses auditory cues to unobtrusively present relevant information, such as the availability of one’s colleagues. ‘ShareMon’ [27] uses subtle background audio to make computer users aware of background file sharing events on their computers. More closely related to the ABC ringtones introduced in this paper, Butz and Jung [28] present a concept to subtly notify employees of museums or shopping malls of incoming phone-calls or other messages, by modifying the ongoing music playing in the background. Each employee is assigned an instrument, and the addition of that instrument to the soundtrack is an unobtrusive notification for the related employee, which may not be detected at all by others.

One review of literature on peripheral displays [29] shows that most such studies use informal evaluation methods, in which users interact with the displays once or twice and report mainly on the initial *enjoyment* of the display, while only a few assess the *functionality* and *usability* of peripheral displays. A number of specific evaluation methods for peripheral interaction have been proposed in related work, involving concrete subjective measures to assess peripheral displays such as ‘awareness’, ‘distraction’ and ‘usefullness’ [20, 30]. Additionally, evaluation strategies have been proposed involving deployment of displays in the real context of use for an extended period of time [2, 29]. While not intended to evaluate peripheral interaction or other HCI concepts, Horton et al. proposed that it is possible to use EEG to decipher attentional focus between two possible speakers based on neural responses to the envelopes of natural speech [31].

The authors know of no studies in which psychophysiological or psychoneurological measures were used to quantitatively detect whether or not "peripheral information" is perceived in the periphery of the user's attention before moving to the center.

3 Experimental Procedure

The smartphone is ubiquitous and combines great convenience with an equally great possibility of interrupting users at any time. Phones ringing in meetings or on crowded trains can be annoying, but sometimes the threat is greater than simple annoyance. The World Health Organization (WHO) has stated that driving is the leading cause of death among young adults world-wide, and that distraction due to phone use is the fastest growing contributor [32]. It is important to stress that this is not only due to either the physical demands of holding and using a phone, or to a failure in conscious and deliberate task switching between using a phone and driving [32]. Phone use while driving is also dangerous because notifications from the phone pre-attentively interrupt the peripheral subroutines that are an subconscious part of safe driving. It is precisely because these routines and this shift are subconscious that the driver is unaware of the danger [1]. We investigate Brown's [11] claim that ringtones designed according to his ABC model will alert and inform the intended recipient, without interrupting their routine performance of another task that requires both conscious, attentive work (reading random symbols and numbers and checking for accuracy) and unconscious, peripheral sub-routines (typing quickly).

3.1 Setup and Materials

In order to explore these research questions, an experiment was set up in which we measured participants' psychophysiological and psychoneurological responses to their phone ringing with various ringtones, while they were performing a task that demanded their conscious and unconscious attention.

The experiment was conducted at the Laboratory of Experimental Psychology, in the Department of Psychology of the University Lusófona, in Lisbon, Portugal. This space includes a soundproofed studio equipped to measure and synchronize direct data from EEG and other psychophysiological measures, such as heart rate, respiration rate, and skin conductance, and to track eye movements during the separate use of auditory equipment and computers (see Fig 1). The experiment consisted of 5 phases:

1) Pre-experimental questionnaire (5-10 minutes). Data was gathered on each participant's physical and neurological fitness, their hearing, and their customization of ringtones, as well as their familiarity with computers and smart phones. One participant was excluded because of a previous brain injury.

2) Familiarization period (6 minutes). After the pre-experimental questionnaire, the participants were connected to the equipment required to take the above-mentioned psychophysiological measures, and allowed to familiarize with the high attentional typing task, which will be detailed in the next section.

3) Baseline Trial (3 minutes). After familiarizing with the task and equipment, the participants were instructed to again perform the typing task as quickly and accurately as possible. The sound of a crowded cafe (http://mynoise.net) was played at constant average level of 70 db.

4) Experimental trial: Do ringtones affect performance? (3 to 5 minutes). On top of the café sounds, each participant was now exposed to the ringing of their own phone, which was hidden from direct line of sight at the workstation. The phone rang 15 times using a variety of ringtones detailed later in this paper. Participants were aware that their phone would be ringing during the experiment, and that there would be different ringtones playing. They were not aware of the full range or of the order.

5) Post-experimental questionnaires (5 to 15 minutes). After the experiment, participants filled out two additional questionnaires. The first used Likert-style scales to capture their impressions and feelings regarding the experience and their belief that they could hear and even distinguish between the different ringtones. The second questionnaire was a modified System Usability Scale (SUS) used to evaluate each participant's impression of the comparative usability of the ABC ringtones [33].

Fig 1. Example of the experimental setting.

3.2 Participants

As is commonly reflected in the literature [34], the duration of the experimental set up and the intrusive nature of the psychophysiological measurements left us with a small pool of participants. Our pool included 10 people (4 female) between 19 and 29 years of age (median = 21.5, SD = 3.31). Each participant reported using computers and smartphones on a daily bases. On average, the participants reported that they rarely found it hard to hear their own phone ringing in a crowd or to hear their own phone when they were concentrating on another task, and that they sometimes decided not to answer a phone if it would interrupt what they are doing.. None of the participants reported any perceptual or cognitive difficulties, which might have an effect on their performance.

3.3 Typing Task and Performance Rate

To ensure that participants were focused on a different task while hearing the ringtones, they were asked to perform a high attentional task. We chose to use an online typing task in which participants were asked to type a random series of characters as quickly and accurately as possible. In order to avoid language bias in our multilingual sample population, the task was limited to numerals and mathematical symbols. Participants were instructed to attempt to achieve the best possible success rate on the typing task in the least possible amount of time. These two factors were counterbalanced and used to calculate a performance score for each participant. Typing rate (keystrokes per second) was used as a measure of task engagement. A baseline of performance and Beta Wave activity was established for each participant during stage 3 of the experiment. This baseline is captured to compare each participant's performance and Beta Wave activity in stage 4 to their own baseline, as is common in a within-subjects experimental design.

The average baseline in keystrokes per second for each participant varied between 0.69 and 2.47 (mean 1.57). Keystrokes per second during the experimental trial (with ringtones) varied between 0.75 and 2.46, with a mean of 1.58.

3.4 Ringtones

The ringing of each participant' phone involved two variables: volume and ringtone. Volume was set at three different levels, and 5 different ringtones were used. Each participants' phone rang 15 times during phase 4 of the experiment: each ringtone was played once at each volume level. The time in between each ring was randomized between 10 and 20 seconds. The order in which the different ringtones were played was randomized, but non-repeating.

The volume levels were defined according to sound intensity measured in decibels (dB): 1) soft (55-65 dB); 2) medium (65-75 dB); and 3) loud (75-85 dB).

The ringtones were 1) the participant's normal ringtone; 2) the voice of a loved one saying a low-valence word; 3) the voice of a loved one saying the participant's name; 4) a stranger's ringtone, and; 5) the voice of a stranger saying the participant's name. The recordings of their loved ones were generated by the participants themselves, the evening before participating in the experiment, using the default recording and ringtone customization software on their own smartphones.

3.5 Physiological and psychoneurological measurements

During the experiment 5 EEG electrodes placed on the midline were used to measure the activity in different regions of the participants' brains as modelled in the ABC model of HCI [35]. The EEG signal was continuously recorded using Brain Vision v1.05 (BrainAmp Standard from Brain Products, GmbH). We used 5 Ag/AgCl active electrodes in accordance with the standard 10-20 international system with left mastoid reference and a sampling rate of 1000Hz. Figure 2 shows the sensor placement areas used for surface EEG. A notch filter was applied to these data during the recording. Input impedances were kept below 10 kΩ by careful scalp preparation. As well as the EEG, we also measured respiration rate, skin conductivity and heart rate, and tracked each participant' eyes in order to capture their gaze and eye-blinking.

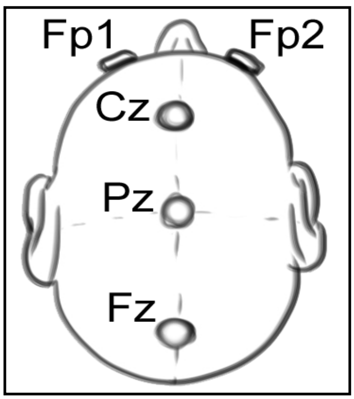

Fig 2. Illustration of the EEG sensor layout.

3.6 Data pre-processing

Data processing was done in EEGLAB toolbox v12 for MATLAB [36]. EEG analysis was performed only for the baseline and experimental trials, using the continuous data from the sensors depicted in Figure 2. Each individual file was segmented into 300s epochs for both the baseline and the experimental trial.

Continuous data was high-pass filtered with 0.5 Hz FIR filter. Independent Component Analysis (ICA) using SOBI algorithm [37] was performed to detect noise from eye-movements and blinks. Components showing higher amplitude frontal activations were removed from the analysis (see [38] for a more detailed description of this procedure). Following ICA decomposition, the data from the baseline and experimental trials was then segmented in 1s epochs. Fast Fourier Transformation (FFT) [37] was computed separately for the 300 epochs the baseline and experimental trials to detect the power density in the beta frequency range (12– 30 Hz). This analysis produced a near continuous record of beta power density for each electrode site during each of the 300s trials These data were then exported to MS Excel in order to calculate the mean beta activity for the baseline and the experimental trial for each specific ringtone from the raw data files. This was done for the five electrode sites, by the five ringtone categories, for each of the 3 volume levels. This database was exported to SPSS for statistical analysis.

3.7 Data post-processing

The first step in processing this extracted data was to calculate the Delta activation (baseline subtraction): the difference in beta activity from the baseline condition. This resulted in a database with 75 new variables describing the delta power density in beta wave. We conducted within-subject comparisons. Omnibus ANOVA was performed to test interaction between factors under study (Electrode site X Ringtone category X Volume). The results showed a 3-way interaction effect between these variables ($F(32, 288) = 1.531$; $p = .038$). We tested this interaction by comparing the activation in delta band for each ringtone category separately for channel and volume level. The results are reported below.

4 Results

A future paper will present analysis of the impact of the different ringtones on both task performance and other psychophysiological reactions (e.g. heart and respiration rates, and eye-tracking). This article is focused on the potentially peripheral perception of ringtones made up of high-valence words spoken by a loved one. We will summarize these results before discussing them in detail.

4.1 Summary

When our participants heard their name spoken in the voice of a loved one at the lowest volume level (55-65 dB - softer than the background noise), the EEG captured reactions in the pre-attentive regions of the brain. The increased activity shows perception of the ringtone, even though its volume was too soft to hear.

Participants reported being aware of the voice/ringtone despite the low volume and lack of normal reaction in the front of the brain. This may imply that the information (of a ringtone) had moved internally - slipping through the filter as previously theorized [13, 14] and measured [17, 18] with natural communication. This may indicate that the ringtone was indeed perceived through *peripheral perception*, and then *centered*, as theorized in both Weiser's "Calm Technology" [7] and the notion of peripheral interaction [2].

4.2 Results

Figure 3 shows the mean Beta wave density at each of the 5 sensor locations when different ringtones are played. In these graphs, the mean values of delta activation in beta activity are shown separately for low volume (Fig 3 top), medium (Fig 3 middle), and high volume (Fig 3 bottom). The Y-axis represents the density of the activity, normalized for each participant against their own baseline while performing the same task in the same environment, but without the ringtones. The X-axis shows the EEG channels ranging from the front of the scalp to the back, which corresponds to the range from the 'anterior electrode sites' to the 'posterior electrode sites', as indicated at the top of Figure 3. The anterior sites (those toward the left of the X-axis) reflect conscious, attentive brain activity, while the posterior sites (those toward the right of the X-axis) reflect brain activity at pre-attentive levels of awarenss, such as routine activities and subconscious thoughts.

The data in Figure 3 show a trend toward significance for the comparisons between ringtone categories only in the Pz channel (posterior site) for the low volume condition ($F(4, 36) = 2.317$; $p = .076$). The largest difference from baseline in beta activity was obtained for "Loved one saying name" in the Pz channel, whereas the lowest value was for "own ringtone". However, the differences found in the ANOVA between ringtone categories did not survive post-hoc analysis with Bonferroni correction ($p =.10$).

As seen in Figure 3, differences from the mean beta-wave baseline are either positive (above the bar) or negative (below the bar). When looking again at the results for the ringtone "Loved one saying name" under the low volume condition, we observe increasing positive differences when moving towards the posterial brain area. It is clearly visible that the soft voice of a loved one speaking one's name triggered more Beta-wave activity in the posterior electrode sites compared to the baseline, while only a small increase compared to the baseline was measused in the anterior electrode sites.

As an example of increased brain activity in the posterior area, Figure 4 illustrates the data from one participant when hearing a stranger's ringtone (left illustration in Fig 4) and when hearing a loved one speaking the participant's own name (right illustration in Fig 4). Clearly, hearing one's name spoken by a loved one increases Beta-wave activity at the back of one's brain. Contrarily, hearing a stranger's ringtone clearly increases Beta-wave activity at the front of the brain.

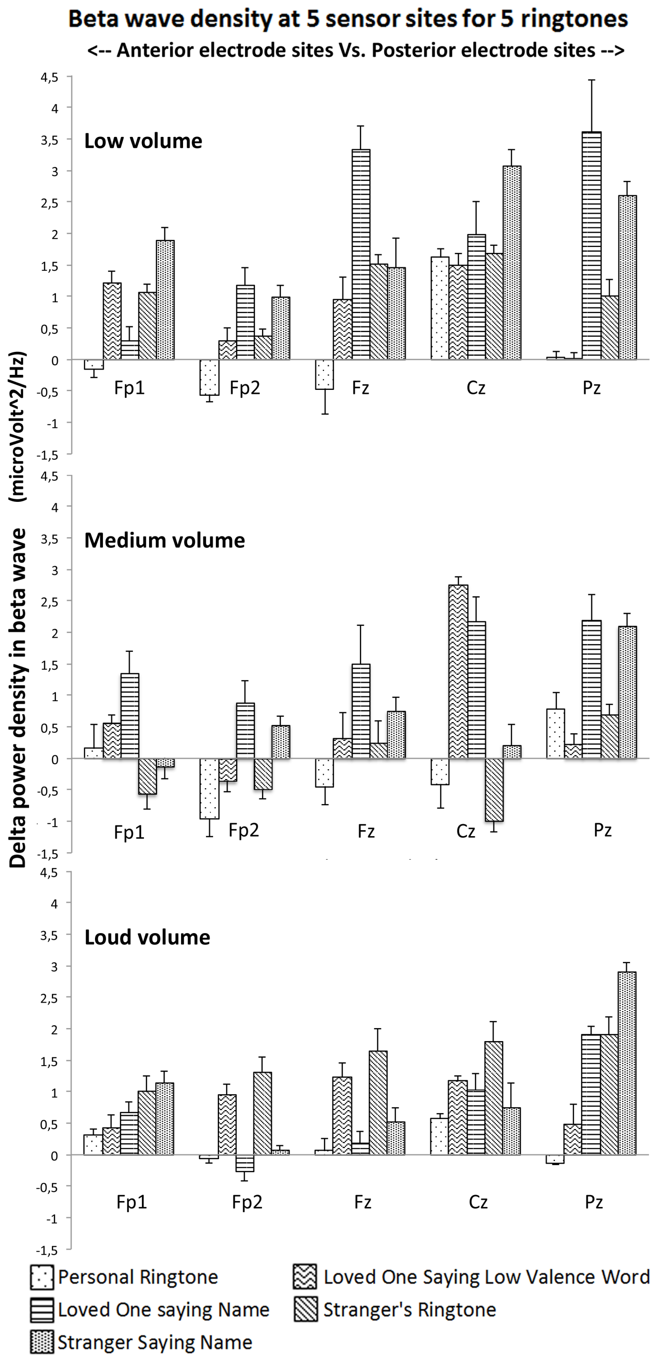

Fig 3. Change in beta wave density at low, medium, and loud volume.

Although statistical significance did not survive our post-hoc Bonferroni correction, the results from our small sample point towards the possibility that hearing a loved one say own's own name at low volume may trigger a relatively high response in the posterior brain, reflecting pre-atentive processing.

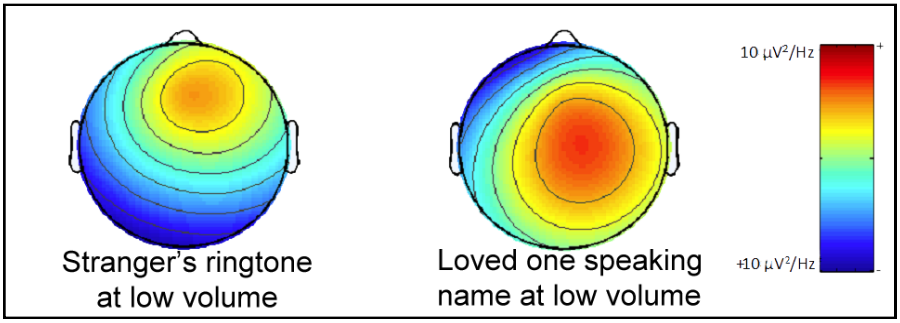

Fig 4. Illustrating the separation of Beta-wave activity between the pre-attentive and attentive regions of the brain.

5 Conclusions and Future Work

The aim of the study presented in this paper was to demonstrate and test a proposal for 'ABC ringtones', inspired by the concept of Calm Technology [7], that could be easily put to use by the general public without the need for any additional hardware, software or training. This idea was conceived with the understanding that an ABC ringtone would provide peripheral information regarding both caller and intended recipient while being less distracting to people nearby at the same time. In our experiment with ABC ringtones, we used EEG measurement techniques to assess the extent to which these ringtones could be perceived in the periphery of attention. Peripheral perception can be seen as the basic concept behind calm technology [7], peripheral interaction [2] and related fields (e.g. [8, 9, 39]).

Though the findings presented in this paper are merely preliminary, they seem to indicate that it might indeed be possible for people to perceive particular auditory information (i.e. one's own name spoken in the voice of a loved one, based on the cocktail party effect [13]) through peripheral perception. Those ringtones triggered relatively dense brain activity in the posterior area of the brain which is responsible for pre-attentive processing, even though the volume at which they were played was softer than the background noise.

These preliminary findings have the potential to contribute to the field of HCI - and to peripheral interaction in particular - in two ways. First, they would present a means of empirically evaluating the concept of peripheral perception, where limited or no such means are known in related studies. Second, having found preliminary indication that the human brain seems to have the ability to perceive and understand seemingly imperceptible audio information (i.e. cocktail party effect), this long-established human skill can be deliberately used in HCI. The concept ABC ringtones explored in this paper presents an example of this, which can easily be applied using current technologies, and could impact the way we use technolgy in everyady life. Since it is understood that technologically-generated distractions contribute to the leading killer of young people participating in traffic [32], this concept could be investigated as a mitigating factor. It may be that being informed peripherally of the identity of a caller will prevent over-reaction. Relying on peripheral perception, alerts and ringtones could be developed to provide information to the intended recipient without interfering in their performance as a driver.

Future testing aims to quantify the levels of volume and intonation that are most effective, and to look for crossover effects with multiple simultaneous participants. Additionally, we aim to study the effects of a wider range of affective content (tone of voice and non-verbal sounds such as laughter or unusual breathing patterns).

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