HHS Public Access
Author manuscript
Proc ACM Int Conf Ubiquitous Comput. Author manuscript; available in PMC 2018 October 03.

Published in final edited form as:
Proc ACM Int Conf Ubiquitous Comput. 2015 September ; 2015: 719–730. doi: 10.1145/2750858.2805843.

Mindless Computing: Designing Technologies to Subtly Influence Behavior

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Abstract

Persuasive technologies aim to influence user's behaviors. In order to be effective, many of the persuasive technologies de-veloped so far relies on user's motivation and ability, which is highly variable and often the reason behind the failure of such technology. In this paper, we present the concept of Mindless Computing, which is a new approach to persuasive technology design. Mindless Computing leverages theories and concepts from psychology and behavioral economics into the design of technologies for behavior change. We show through a systematic review that most of the current persuasive technologies do not utilize the fast and automatic mental processes for behavioral change and there is an opportunity for persuasive technology designers to develop systems that are less reliant on user's motivation and ability. We describe two examples of mindless technologies and present pilot studies with encouraging results. Finally, we discuss design guidelines and considerations for developing this type of persuasive technology.

Keywords

Persuasive Technology; Behavior Change; Mindless; Nudging; Subliminal; Subconscious; System 1; System 2; H.5.m Information Interfaces; Presentation: Misc

INTRODUCTION

Persuasive technology is a rapidly evolving area of ubiquitous and wearable computing and is growing in popularity both in academic and private sector research groups. Designers of persuasive technologies use different design strategies in order to persuade users, such as Foggs' seven types of persuasive strategies [18]. However, a large part of the strategies used rely on conscious awareness of the user about the behavior to change. While this has been an effective way to develop persuasive technologies, there are several limitations and potential issues involved, such as the strong reliance on user's motivation and humans limited capacity for self-control [31].

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Many of the current persuasive technologies are heavily impacted by both internal factors and environmental contexts, such as what mood the user is in, where they are, how much stress they are under, or who they are with, which are unpredictable and subject to change. These internal factors can even disrupt people's interaction with the technologies, which may counteract positive aspects of the interventions.

The limitations of existing persuasive technologies bring up an important question: How can we develop persuasive tech-nologies that are subtle and does not rely too much on people's motivation and ability to be effective? Aiming to answer this question we present in this paper the concept of Mindless Computing, which is a new approach to persuasive technology design. In this context, mindless refers to the automatic thoughts and behaviors that occur efficiently and without the need of conscious guidance or monitoring [33]. Therefore, we define a technology as a Mindless Computing technology if it is *a mobile or ubiquitous, persuasive technology designed to subtly influence the behavior of the user without requiring their conscious awareness*.

The concept of Mindless Computing was created from previous studies that show that our behaviors are controlled by two main cognitive systems: System 1 and System 2. System 1, also known as the "automatic mind", is fast, automatic, and can occur subconsciously. System 2, which is also called as the "reflective mind", is slow, conscious, and operate in a controlled fashion [22]. The central idea of our approach is to design technologies taking into account our automatic mind (System 1). Behavior change based on the automatic mind has been studied in several research domains, including psychology and behavioral economics. Researchers have developed theories and demonstrated techniques in which a subtle change in behavior can occur while the user is unaware that the behavior had changed. Therefore, the aim of this paper is to highlight the importance of leveraging behavior change strategies that rely on the automatic mind and show how to incorporate these strategies in the design of mobile and ubiquitous technology for behavior change.

This paper provides three main contributions:

- First, through a systematic review on persuasive technologies we show that most technologies are designed to act on System 2 processes, and we show how this explains some limitations of current persuasive technologies;
- Second, we present two examples of Mindless Computing technologies with preliminary evaluations of their in-terventions;
- Third, we provide design guidelines and considerations for designing Mindless Computing technologies.

THEORIES OF AUTOMATIC BEHAVIOR

Automatic Mind and Reflective Mind

There is a set of theories called dual process theories that divide the mental processes underlying behavior into two categories. By leveraging previous studies on heuristics and biases, Kahneman presented a generalized dual-process theory that distinguishes two kinds of mental processes: System 1 and System 2[30]. System 1 is characterized as fast, parallel, automatic, and require little or no effort, while System 2 is described as slow, serial, effortful, and operates in a controlled fashion [30][22]. When individuals are thinking about a decision to take, such as whether or not to go to the gym or to eat healthy food, they are using System 2. When individuals make a “disgust face” when seeing moldy food or when they orient to the source of a sudden sound they are using System 1. Both systems are always active and interacting with each other. System 1 is always providing suggestions for System 2, including impressions, feelings and intuitions, and in most situations System 2 adopts the suggestions of System 1 with little or no modification [30].

Among the dual-process theories, two of the most prominent are the elaboration likelihood model (ELM) [49] and the heuristic systematic model (HSM) [10]. The essence of these models concerns the conditions in which different aspects of a message influences the persuasion. In the ELM there are two major routes for persuasion: the central route and the peripheral route. Under the central route, persuasion will likely result from a person’s careful consideration of the information presented, while under the peripheral route persuasion results from a limited examination of the information available or by the use of heuristics and other types of shortcuts. The HSM model is very similar to the ELM, also containing two basic persuasion processes that influence individual’s judgments and behavior: the systematic processing and the heuristic processing. One concept of the model is the Sufficiency Principle, that states that people are partially guided by the “principle of least effort”, in which in some situations the mind processes information with the least amount of effort (heuristic), and in other situations it would use more effortful processing (systematic). Both in ELM and HSM the assumption is that people do not have the requisite knowledge, time, or opportunity to thoughtfully think about everything, so the use of System 1 helps to save people’s energy, time, and mental effort.

Nudging

One concept that can leverage both System 1 and System 2 to influence people’s behavior is nudging. Thaler and Sunstein define the concept as “any aspect of the choice architecture that alters people’s behavior in a predictable way without forbidding any options or significantly changing their economic incentives” [58]. A simple example is a cafeteria manager that replaces cake with fruit in the impulse basket next to the cash register aiming to encourage customers to buy more fruit and less cake. The customers still have the option of buying cake if they want, but the way that the choices are offered subtly influence them to pick more the fruit than the cake.

The idea of nudging has been applied in various contexts. For instance, in order to influence drivers to reduce the car speed, some cities used different nudges in the road design, including 3D paintings of kids chasing balls and lines painted across the road in a way that makes drivers think that they are driving faster than they actually are. This last approach has been successfully applied by the Chicago’s Department of Transportation, since in the six months after the lines were painted there were 36% fewer crashes than the six-month period the year before [42].

The theory of Nudge was developed from previous studies that show that we can commit mistakes and act against our own interests without realizing that [30]. A common example is the bandwagon effect, in which a person decides to do something just because many others are also doing it, regardless of her own beliefs [12]. Another example is the size of the plate where we put our food, which can influence how much we eat [62]. According to Kahneman [30], many of our mistakes and ‘irrational’ decisions can be explained by the way that our automatic mind (System 1) works. Even though the System 1 saves our energy, time and mental effort, it can also lead us to jump into conclusions and take decisions without thinking. However, it is possible to use the way that the automatic mind works in our favor, by using nudges to influence behavior in a positive direction.

The concept of nudging is similar to the concept of mindless computing. Both concepts refer to interventions designed to influence people’s behavior. Nudges can be effective by relying both on the rational mind (System 2) and the automatic mind (System 1)[25]. The intervention of a mindless technology, on the other hand, relies specifically on the automatic mind. A nudge can be a simple and static object, such as a sticker in the form of a foot to lead pedestrians in a certain direction. A mindless technology, however, always involves some level of computing, which allows more robust, intelligent and personalized interventions. Finally, designers of nudges have traditionally focused on changing features of the environment for group-level interventions rather than personal-level interventions [47]. This can be, for instance, the impulse basket in a cafeteria (to influence customers to eat fruits) or the painted lines in a road (to influence drivers to slow down). A mindless technology, on the other hand, can be not only a feature of the environment but also an object that change the way a person perceives the environment. By presenting certain stimuli to the user (visual, auditory, tactile or olfactory) the technology can influence the way the user experiences their activities, which in turn can trigger automatic behavioral responses. A mindless technology does however rely heavily on principles of System 1 nudges to trigger personalized behavior change without conscious effort.

Subliminal Stimuli

One way of triggering fast and automatic responses (System 1) in individuals is by using subliminal stimuli. Researchers have been evaluating the impact of subliminal stimuli on people’s behavior and emotion for a long time. A stimulus is called subliminal when it is below the threshold of conscious awareness [15], and it can be provided in different ways to participants. With visual stimuli, researchers often prime participants with specific images and determine if the images elicit different responses. For the auditory stimuli, one common method used is masking, in which the target auditory stimulus is hidden in some way.

There is quite a bit of evidence that subliminal stimuli can affect behavior. These effects have been observed on a variety of behaviors, including social cooperation, competitiveness and memory retrieval [37]. For example, Wheeler and colleagues found that priming the African American stereotype led participants to perform poorly in a standardized test [65], compared to control groups. In another study, researchers found that older adults perform better on memory tests after subliminal exposure to words related to wisdom rather than senility [35].

The idea of subliminal stimuli has also been explored in the field of Human Computer Interaction. In this case, the focus has been mostly on alleviating the cognitive load associated with interacting with varied devices. The idea is to provide subliminal cues that allow users to receive additional information even when there is no capacity left for information transmission in a traditional way [54]. Examples of research include a just-in-time memory support using subliminal cues delivered in a head-mounted display [16] and one aid for visual search tasks [41]. HCI Researchers have also investigated how subliminal cues can influence people's choices. In [1], for instance, the authors used subliminal cues to influence the selection of items in a virtual refrigerator [1].

Mindless Computing may use subliminal stimuli to trigger behavior change subconsciously. However, there are many other ways to accomplish this. As we will demonstrate in later sections, it is possible to influence the user's behavior by providing a subtle but perceptible stimulus.

SYSTEMATIC REVIEW OF PERSUASIVE TECHNOLOGIES

Researchers and designers have combined different strategies to build technologies to influence people's attitude and behavior such technologies are referred to as persuasive technologies [19]. Persuasive technologies can be designed to influence diverse behaviors, such as to practice physical activities [14] and to keep more sustainable habits [21].

Since people's behaviors are influenced by the automatic mind (System 1) and the reflective mind (System 2), one question that arises is: How many persuasive technologies rely on strategies that require conscious awareness of the user (System 2) to be effective? In order to investigate this question, we performed a systematic review of papers describing persuasive technologies. We focused our attention in four conferences: Ubicomp, CHI, Pervasive Health and Persuasive. The papers of these conferences are available in three electronic bases: ACM Digital Library, IEEE Explore and Springer. In order to find relevant papers in these electronic bases, we used the following keywords: persuasive technology, captology, behavior change, nudge, nudging, subliminal, subconscious, behavioral economics, and priming. Since the Persuasive conference is focused on persuasive technologies, instead of using keywords in the search we reviewed all papers published in this conference since its inception (2006) until 2015. Once the articles had been obtained, one researcher (one of the first authors) read through all titles and removed the duplicates. This phase yielded a result of 885 articles and formed the basis for the next step in our selection process.

We obtained the abstract of all articles identified in the first phase and both first authors read through the abstracts, with the following exclusion criteria: i) Exclude if the paper does not present a persuasive technology; ii) Exclude if the paper does not present a mobile or ubiquitous technology; iii) Exclude if the paper does not present an evaluation of the technology or the intervention. After each researcher had gone through the papers we compared results. Where we disagreed as to whether to keep or remove a paper, we discussed the matter until we reached agreement. This process reduced the number of articles to 252, and agreement between researchers was 'good' (Kappa value of 0.71).

The full text for all 252 papers was obtained and both researchers read through all the papers with the same criteria for exclusion in mind. The final number of papers selected for the review was 176. The agreement between researchers was 'good' (Kappa value of 0.76). The full list of papers can be accessed via: http://pac.cs.cornell.edu/files/systematic_review.pdf.

We chose to classify the 176 papers identified according to the kind of System (1 or 2) the technology presented in the paper acts upon. Each researcher classified the 176 papers individually, before comparing the results. The agreement between researchers at this stage was 'very good' (Kappa value of 0.87). Disagreements were discussed until a consensus was reached on the classification. After the discussion, we agreed that 165 papers describe persuasive technologies that were designed to focus on the rational mind (System 2) and only 11 papers present technologies that focus on the automatic mind (System 1).

System 2 Technologies

The results of the systematic review show that most of the persuasive technologies were designed to act upon the reflective and rational mind (System 2). One common characteristic of the technologies is the reliance on the motivation and/or ability of the users, so they require conscious attention and effort from individuals to change their behaviors.

Designers of persuasive technologies that focus on System 2 often leverage existing theories and models, both to make decisions about which features to implement and also to decide how to implement such functionality [27]. Among the theoretical models used, one of the most popular is the Transtheoretical Model (TTM) [51]. The model assesses an in-dividual's readiness to act on a new healthier behavior, and provides strategies to guide the individual through stages of change. It has been used to encourage diverse behaviors, such as to practice physical activities [14] and to make healthier meal choices [23].

Another common theory leveraged in the design of persuasive technologies that act upon System 2 is Goal-Setting Theory [36], which suggests that two dimensions of goals influence performance: difficulty and specificity. According to the theory, the best performance should be achieved by focusing on specific and challenging goals, yet the goals should be realistic to achieve [13]. Several technologies were designed using this theory, including tools to help people reduce their stress levels [32] and to increase their physical activities [43].

In addition to behavioral theories and models, researchers have used different strategies to persuade the users. Among the strategies used, some of the most popular are the seven persuasive strategies presented by BJ Fogg [19]: Reduction, Tunneling, Self-monitoring, Conditioning, Surveillance, Tailoring and Suggestion.

One of the most used persuasion strategies is self-monitoring [31]. Commercial and research applications have incorporated automated sensing or manual tracking features that allow users to monitor their activities and potentially make changes based on that [11]. These applications offer different ways of presenting feedback. In UbiFit [14], for instance, the wallpaper of the mobile phone shows abstract representations that change based on the user's activities, encouraging the user to reflect about his lifestyle.

Another common strategy used in persuasive technologies is conditioning, which is usually achieved by providing positive or negative reinforcement [31]. One example of application using this strategy is Fish'n'Steps, in which the growth and activity of a virtual fish is linked to the daily step count of the user. The feedback is provided with a fish happy and growing (positive reinforcement) or crying and not growing (negative reinforcement).

System 1 Technologies

The result of our systematic review shows that only 11 of the 176 papers describe persuasive technologies designed to focus on the automatic mind (System 1). Furthermore, only two papers explicitly mention behavioral theories that inspired the design of the technology [55][34]. In [55] the authors present an ambient installation that influences people to take the stairs instead of the elevator. The work was inspired by previous studies that show how fast and frugal heuristics can influence people's behavior [60]. In [34] the authors evaluated persuasive technologies to influence healthy eating [34]. In their work, they showed how to leverage behavioral economics approaches in the design of persuasive technologies.

The System 1 technologies found in the review were designed to influence different kinds of behavior, including: decrease energy consumption [24][39][38], practice physical activities [55], improve behavior during social interactions [52][3], keep proper posture while sitting [46], look at a shop window [53], eat healthy snacks [34], drink water [2], and correct bad posture while playing violin [61].

Among the approaches used in the persuasive technologies that focus on System 1, the most common is to change aspects of the environment. 8 out of the 11 papers found use this approach [24][39][38][3][55][46][53][2]. All technologies described in these papers use visual cues in the environment to influence people's behavior. One approach used in papers that focus on energy consumption is to use pre-existing color associations and change the colors of the environment to trigger different perceptions and sensations [24][39][38]. Another approach used is to deploy ambient installations that are playful and attractive in order to lure individuals to take the stairs more than the elevator [55], to drink in a water fountain [2], and to look at a shop window [53]. Other researchers used subtle feedback that act in the periphery of the user's attention [3][46].

Another approach used in the persuasive technologies found is to use mobile technologies. In [52] the authors used audible cues to reduce dominance in collaborative tasks [52]. In [34] the authors used a robot that influences people to make healthier snack choices by making the choices more accessible and convenient. Finally, in [61] the researchers present a technology that provides a gentle vibrotactile feedback to help people correct bad posture while playing violin.

ISSUES WITH THE FOCUS ON SYSTEM 2

While persuasive technologies drawing from System 2 (slow) processes have achieved enormous success, there are limitations stemming from that sole focus on System 2. In this section we describe some issues with the reliance on System 2 that can compromise the effectiveness of persuasive technologies.

Reliance on User's Motivation and Ability

In [20] BJ Fogg argued that there are three reasons that restrain individuals from performing a target behavior: i) lack of motivation; ii) lack of ability; and iii) lack of a well-timed trigger to perform the behavior. For example, a woman could be motivated to lose weight after hearing jokes from others (trigger), but without knowing how to lose weight (lack of ability) she could have problems to achieve her goal.

Several persuasive technologies were created based on this assumption that users need to have motivation, ability and a trigger to change their behaviors. Because of that, whenever a technology does not affect people's behaviors as expected, the researchers often argue that users did not have the ability or were not motivated enough [20]. For instance, previous studies stated that wireless fitness trackers tend to result in only short-term adoption and changes in behavior, and one common explanation is that users lose motivation over time [57].

Even though motivation and ability are important factors in influencing behavior, previous studies showed that individuals can also change their behaviors without being aware of it. Therefore, the argument that individuals need to be motivated and have the ability to perform a behavior only holds with persuasive technologies that rely on System 2 to work properly.

Since persuasive technologies that rely on System 2 put a lot of burden on the user, the behavior change is often expected to be a long-term process. One of the reasons is that many behaviors are part of people's daily lives, so a single change often requires individuals to change their routines, which is not an easy task [31]. Furthermore, the literature shows that the human capacity for self-control is limited, so behavior change setbacks can always occur, especially in situations where self-control resources are drained by demands in other areas of one's life, such as when individuals are stressed, in bad mood, or distracted with many tasks [31]. This is why several researchers advocate that in order to evaluate health behavior change it is necessary to conduct a longitudinal study over several months or even years [51], since it takes a long time for a behavior change to truly stick.

Feedback and Impact on Performance

In many circumstances it is important to keep the focus on long-term behavior change, since the goal of the person is not something that can be achieved in one single activity. For instance, a user that uses a fitness tracking device with the goal of losing weight will reach his goal only if he starts to practice physical activities regularly. However, there are situations in which a single change of behavior can have major consequences for the individual. For instance, a driver that is persuaded to reduce the car speed could avoid an accident, and a person that adjusts their behavior during a business meeting could create a better first impression. In these situations a technology could provide feedback after the activity, but then it could be too late. These examples show how the timing of the feedback is an important aspect in behavior change technologies.

One aspect that has to be taken into account in the design of persuasive technologies is how to provide feedback without interrupting the user. This is when persuasive technologies based on System 2 can fail. Since System 2 processes involve conscious reasoning, users have to direct their attention to the technology when needed, which often involves pausing or stopping their current tasks. For instance, a common approach used in persuasive technologies is to present data about the user's behavior, so that he can reflect and change their behavior if needed. This approach requires the user to look and process the information presented, which may not be feasible in situations that the user is busy with other tasks.

The problem with this conscious interaction is that not all self-regulatory processes require conscious awareness and attention to operate smoothly, and a substantial portion of day-to-day behavior has been thought to occur automatically or mindlessly [4]. In situations in which the performance of a task has become automatized, conscious thought about the task can impair the performance while performing it, which has been known as the "centipede effect" or "humphrey's law" [12]. Baumeister [5], for example, argues that conscious attention to skilled manual performance can disrupt that performance. He shows that asking people to think about what their hands are doing makes them worse at a manual game, as does letting them know that they are being evaluated.

MINDLESS COMPUTING

There are several issues involved in the reliance on the reflective and rational mind (System 2) in the design of persuasive technologies. However, the systematic review presented in this paper shows that most persuasive technologies were designed taking into account only the reflective mind. This strategy has been applied in different contexts and several studies have shown empirical evidence that this kind of technology can indeed persuade users. On the other hand, given the issues of System 2 technologies we argue that it is necessary a new approach for designing persuasive technologies. In order to bridge this gap, we present in this paper the concept of Mindless Computing, which is a new perspective for persuasive technology design. The main idea of Mindless Computing is to design persuasive technologies that can subtly influence the user's behavior without requiring their conscious awareness.

Mindless technologies can fill some gaps in the design of persuasive technologies, by both subtly integrating itself into the daily lives of users and by influencing users' behavior requiring little effort and attention from them. In order to clarify how the concept can be used in practice, we present in the next section two examples of mindless technologies.

EXAMPLES OF MINDLESS TECHNOLOGIES

In order to demonstrate how behavior change technologies can be designed using System 1 processes, we present in this section two examples of mindless technologies. For each example we conducted a pilot study to evaluate the effectiveness of the interventions. Both pilot studies were approved by the local ethical committee.

In the first example, the Mindless Plate, we present a technology that leverages perception bias to create an illusion to sub-consciously influence individuals perception of food portion size. In the second example, we present a mobile application that can influence the way people speak by manipulating the pitch of their voice and playing it back to them in real-time.

These examples demonstrate how to develop mindless technologies, which leverage behavioral theories based on the automatic mind (System 1) in order to subtly influence people's behavior. It is important to note that the decision to start using a mindless technology is a conscious process (System 2). In the examples presented in this paper, the user has to make the decision to pick up and use the Mindless Plate or turn on the mobile phone application that manipulates the pitch of their voice in real-time. However, once the user starts to use the technology the behavior influence works in parallel with the user's activity, without interfering with their main task.

Example 1: Mindless Plate

Mindless Computing technologies can leverage our most basic senses to instantaneously influence different aspects of our daily lives. Perception bias has been shown to be an effective medium for creating illusions, which can augment individual's perception of different attributes of an object such as size, color, and sound. The Mindless Plate (Figure 1), is a Mindless Computing persuasive technology that leverages perception bias to subconsciously create the illusion (the Delboeuf illusion [45]) of more food on a plate.

Background and Motivation—Food and branding research groups have leveraged the Delboeuf illusion to alter individual's perception of serving size, resulting in the individuals serving themselves smaller portions. One method is using smaller plates or serving utensils, which causes individuals to serve smaller portions of food [62]. This is due to a perception bias that causes individuals to perceive that there is more food on the plate due to the amount of surface area covered or (in the case of serving utensils) that they have served more (expecting the same quantity that they would have with a larger utensil).

Food and behavioral researchers such as Van Ittersum and Wansink have shown that color bias can affect the perceived amount of food on a plate [62]. This illusion is a result of being able to perceive the edges of the food in relationship to the plate. With low contrasts, the edges are harder to distinguish and are somewhat blurred, which can cause the illusion that the plate extends the actual food on the dish. With high contrasts in color, the edges of the food and gaps between pieces of food are much more clear, while with low contrast the edges are blurred and the gaps seem filled (as seen in figure 1).

Researchers have also shown that when the width of the rim is larger and is a different color from the center of the plate, in-dividuals perceive that the portion of food is larger than it actually is. This is due to the increased emphasis on the relationship between the outer circle (the plates rim) and inner circle, which increases the effects of the Delboeuf illusion [40].

The Mindless Plate System—The Mindless Plate works by sensing the color of the food that is served on the plate and changing the color of the inner circle of the plate accordingly. This allows for the plate to subconsciously influence users perception of the amount of food on the plate by leveraging the effect of the Delboeuf illusion.

The Mindless Plate consists of two sensors, eight RGB LEDs (Model: WS2812S), a Teensy 3.1 microcontroller, and a digital potentiometer, all of which is packaged into the form of a plate. The rim of the glass plate is painted white, which helps enhance the effect of the Delboeuf illusion by increasing the contrast between the plate's rim and the inner circle, making the inner circle of the plate seem smaller [40]. The sensors include a force sensitive resistor (FSR) for sensing the weight of the food and an RGB light sensor (model: ISL29125) for capturing the color of the food.

The core of the Mindless plate consists of several layers that lie under a glass plate and are enclosed in a plastic case. The RGB LEDs are attached along the side of an optically clear piece of mirrored acrylic which has been fractured across the top, in order to evenly distribute the light across the surface, the luminance (voltage) is controlled via a 10K digital potentiometer. Two small air gaps are placed (approximately 1.6 and 3.2mm) on top of the acrylic with a sheet of light diffusing film placed between each. The RGB light sensor is attached to the bottom of the mirrored acrylic where a small, convex lens is milled into the acrylic, allowing the sensor to capture the light from across the top of the plate. The FSR is cut into the shape of a ring (approximately 152mm inside diameter) and placed on the of the film. Below the mirror acrylic is a layer to house the microcontroller (Teensy 3.1 w/Arm Cortex-M4 processor) and a 2000mAh polymer lithium ion battery.

Experiment Design—In order to evaluate the Mindless Plate, we designed an experiment to determine if participants (n = 12, 3 female, 9 male) perception of portion size was biased when looking at food on two Mindless Plates (one of the plates in high contrast with the color of the plate and the other in low contrast). The plates were placed behind a blinder while an equal amount of food (both in weight and surface area) was placed on them. When ready, the blinder was lifted for few seconds and the participants were asked to look at the two plates (while standing up, looking down on the equally sized portions of food) and report which of the two had a larger portion of food on it. Participants were asked to do this seven times, each with a different type (and color) of food. The foods used were peas (green), kidney beans (burgundy), potato chips (yellow/brown), peanuts (light brown), carrots (orange), rice (white), and crushed pineapple (bright yellow). Participants were asked to choose which plate seemed to have a larger portion size, they were not allowed chose that the two portions were the same size. This was to encourage participants to allow their perception to influence their choice and make a more visceral decision.

In order to maintain consistency, the food was weighed between each user and a barrier (similar to a cookie cutter) was used to ensure that the surface area of each food was equal on the two plates. The different foods were shown in a random order for each participant and the placement of the low and high contrasts alternated between left and right between each food shown. Fine grain (or crumbled) foods were used to avoid participants being able to count the pieces of food.

Foods that would not easily be arranged into equal distributions over the plates were crumbled using a pestle and mortar. Since the aim of the study was to test the participants perception of the portion size, the color sensing capabilities were disabled and the contrasts were manually configured to prevent any inconsistencies with the colors of the plate (such as a change in ambient light levels).

Results—In the study, we found that 73% of the foods chosen to be the larger portion had a low contrast in color with the plate they were on ($p = 0.0011$ as measured by t-tests) as seen in figure 2. Figure 3 shows how the results were distributed across the different foods used in the experiment. The results from this study lead us to conclude that the Mindless Plate system can leverage color contrast to create the illusion that one portion of food is larger than another equal portion. This illusion can be leveraged to bias the estimated portion size either to be larger (with low contrast) or smaller (with high contrast). We believe these findings could be used in the design of a ubiquitous system that subconsciously influences users to serve themselves smaller portions of food.

While currently we have only tested the short-term impact of the Mindless Plate, we believe that there could also be a long term impact on how much food individuals consume on a daily basis. This is due to previous studies on the subconscious impact of illusions, dinnerware, and portion size [63] [62]. These studies have shown that even when individuals are aware of biases, the effect of the bias is only reduced temporarily. As individuals become less conscious of a bias, the subconscious effect of the bias increases, which can be due to repeated exposure to the bias causing them to pay less attention to it, external distractions that shift the user's focus away from the bias, or simply not knowing the bias is present.

One result that we found particularly interesting is the distribution in choices made with rice, which were split between high and low contrast. After evaluating this, we believe that it is due to the nature of the food itself. Rice, when steamed, is an opaque white color. We found that this allows it to partially absorb the light, making it difficult to create a major difference in the two contrast (aside from turning the LEDs completely off). While this phenomenon would need to be further investigated to know for sure, we believe that this may be the cause for the split decisions.

Example 2: Subconscious Influence on People's Voices

In this example we used findings from previous studies that show that it is possible to influence people's voices by making them hear themselves with a pitch shifting as they speak [9]. This process happens automatically and without people's awareness, so it is a good example of how to leverage System 1 theories in the development of persuasive technologies.

Background and Motivation—Face-to-face communication plays a major role in our lives. A major part of the communication process is nonverbal language, which are the messages that we send beyond the words themselves, such as gestures, facial expressions, and voice pitch. These micro-level aspects of social skills are highly important in determining the outcomes of social interactions. However, our nonverbal behaviors are often performed unconsciously and automatically [17], so we can negatively affect our social interactions without realizing that. Among the nonverbal behaviors, the use of voice is one of the most important in impression formation. When we speak, people pay attention not only to what we say, but also how we say it, including aspects such as pitch, volume, and pace. For instance, people with lower-pitched voices are associated as more attractive, dominant and having more favorable personality traits [59]. In fact, pitch can even influence voting behavior [59]. Politicians know the importance of using their voices effectively, which is why many of them have voice coaching [6].

In order to help people improve their nonverbal behaviors, researchers have developed different technological approaches. However, many solutions rely on feedback after the social interaction, which can be too late in some situations such as job interviews, business meetings and public speeches. Other approaches rely on traditional feedback in real-time, but previous studies found that if a person pays too much attention to their own behavior during a social interaction this can have detrimental effects on their performance [50]. The question then is: How to design a technology that positively influence the nonverbal behavior of the user in real-time without compromising their performance?

With this question in mind we developed a mobile application designed to influence the way that the user speaks without requiring their conscious awareness. The design of the application was inspired by previous research that shows that speakers may change the pitch of their voices when they hear their voices played back with the pitch manipulated (either raised or lowered) over headphones [9]. This effect has been tested in a laboratory environment and with subjects producing a small number of utterances, so we decided to try if the intervention is also effective in real social interactions. In the future, a mobile technology could be developed to automatically influence several aspects of people's voices in real-time, including volume and pace. A person could then use this system in situations in which she wants to create a good first impression, such as during a phone interview or public speech.

Description of the System—We developed an iPhone application that shifts the pitch of the user as captured by the commodity microphone using Short Time Fourier Transform and immediately plays back to the user through an earphone. In order to shift the pitch, we used Apple's Accelerate Framework, an API that provides mathematical functions for signal processing. Since the feedback should not distract the user, it was important to minimize the playback delay. To achieve this goal, the Fast Fourier Transform was done over small frames, which allowed us to shift the pitch and play back to the user in less than 50ms. With this minimal delay, the voice is seemingly played back in realtime and does not disrupt the speech flow of the user.

Experiment Design—In this study, we had 14 young adult participants (ages 18–27, 9 females and 4 males), all of which reported to be fluent in English and not having speech disorders or other issues with the vocal tract. The participants were instructed that they would participate of a study to understand how the use of technologies affects social interactions, and all tasks of the study would be audio-recorded. The experiment was conducted as follows.

First, the participants were taken to a sound-treated room where they sat down and were asked to read aloud a technical paper (for a duration of three minutes) as if they were reading it to someone else. While reading the paper, all participants had an earphone (model JVC HA-F140) only in their right ear. Half of the participants received frequency-altered feedback (FAF) through the earphones, while the other half did not receive any feedback. The volume of the feedback was kept low (20% of the maximum volume possible) so that the participants could still hear their own voices. The participants that received the FAF listened to themselves while their pitches were slightly shifted and played back as they were speaking, but they were informed that they were hearing their own voices. There were two different conditions for the pitch shifting. In one condition the participants listened to themselves with a pitch 5% lower than their current pitch (low pitch condition), while in the other condition the pitch was increased in 5% (high pitch condition). Since most people can not perceive how their voices sound to others, the 5% change proved to be a good balance that afforded the participants to perceive their voice as natural while being enough of a change to subconsciously cause the participant to change their pitch1.

After 3 minutes, the participants asked to reread the same text during 3 minutes, but this time the participants that received FAF did not receive feedback, while the others that did not receive feedback listened to themselves with the pitch shifting. The purpose of the reading task without feedback was to use it as a baseline to identify what is the average pitch of each participant, while the reading task with feedback was used to make people get used with the feedback.

After the reading tasks, the subjects were instructed that they would participate of a mock job interview through Google Hangout. The interview was conducted by a confederate located in a different room. The confederate asked 5 typical interview questions, which have been used in the past in another study [28]. All participants were informed that they should answer the questions as they would in a real job interview, so they could provide information about themselves and their past experiences. During the interview, the participants received feedback of their voices with the same pitch shifting that they were exposed during one of the reading tasks.

Finally, the participants were asked to fill out a survey, containing questions asking how they thought they had performed in the interview, how they felt during and after the interview, and to what extent they were able to concentrate on the task.

Results—In order to evaluate if and how much the participants pitch changed as a result of the manipulation, we analyzed the audio recordings using the software program Praat [8]. The audio recording of each user was divided into three files: reading task with feedback, reading test without feedback(baseline), and job interview. Then, we used the software to obtain the mean pitch in Hertz of each baseline and the mean pitch in Hertz of each interview.

The major goal of this study was to identify if the mean pitch of each participant changed during the interview in relation to their baseline. In order to evaluate this, we first converted

[1]The decisions about the volume, the earphone in the right ear and the 5% pitch change were made after a pilot study to find the best way of providing audio feedback without causing distractions.

the mean pitch from Hz to Mel using Douglas O'Shaughnessy's conversion formula [48]. By using the Mel Scale, a psychophysical scale for pitch [7], we can see equal difference in perceived pitch according to human perception. As shown in figure 4, the average difference between the baseline and raised feedback condition for the participants was an increase in pitch by 1.6 Mel, and the difference between the baseline and lowered pitch feedback was a decrease in pitch by 13.34 Mel. The just-noticeable difference (JND) for pitch in complex tones, such as the human voice, under 607.5 Mel (500 Hz) is 1.6 Mel (1 Hz) [56]. This shows that both conditions did in fact show a noticeable difference in pitch change on average.

As Figure 5 shows, not all participants were influenced as intended and one did not change pitch at all. In the lower pitch condition, 5 out of 7 participants lowered their voice pitches in relation to their baselines. The two remaining participants increased their voice pitches, but the changes were very small, one falling below the JND threshold (1.3 Mel, no perceivable change) while the other was above the JND threshold (3.8 Mel). In the high pitch condition, 4 out of 7 participants raised the pitch above the JND threshold while two lowered their pitch below the JND threshold and one showed no change.

The results of this study provide preliminary evidence that it is possible to influence people's pitch during social interactions and this could be a medium for developing Mindless Computing technologies that could potentially influence behavior to improve user's confidence while speaking. Since this is a preliminary investigation, we can not argue that the direction of the pitch change will be the same in other conditions. However, the study showed that most participants changed the pitch of their voice during the job interview, and there is an interesting trend in which the pitch change is in the same direction of the manipulation. Some of these changes were large, such as the subject that lowered his pitch by 42.5 Mel. Even though people's mean pitch can vary, large changes like that often do not occur except if there are other factors influencing their speech. In a future study we plan to recruit a large number of participants and investigate if this trend of pitch change remains. Furthermore, we plan to investigate other factors that may explain some of the unanticipated results from this study, such as Amusia (tone deafness), which has been found to affect around 5% of the population [26]).

DESIGN CONSIDERATIONS

We have shown that few persuasive technologies were designed based on System 1 processes. We then presented two examples of mindless technologies, which demonstrated the feasibility of persuasive technologies that act upon System 1 processes. In order to help the design and development of mindless technologies, in this section we present some design considerations. These considerations are based on System 1 theories and our findings from designing and evaluating mindless technologies.

1. Reflexive not reflective

One characteristic of a System 1 process is that it happens quickly and automatically, so in order for a persuasive technology to be a mindless technology it should leverage this attribute. While many persuasive technologies based on System 2 focus on reflection, the technologies based on System 1 should focus on reflex. The technology should provide a simple and straightforward intervention, resulting in an immediate response of the user. In order to trigger a behavior automatically, researchers can leverage techniques and utilize findings from previous studies, especially from psychology and behavioral economics research. Researchers can also take into account pre-existing associations to colors, sounds, smells and touches. The color red, for instance, can be automatically associated to hot temperatures and to the action of stopping something [38]. A pleasant sound can be associated to calmness and positive feelings.

Another consideration that should be taken into account in regards to instantaneous influence is that behavior change should not be evaluated as a long-term process, but as a short-term process that happens right after or in parallel with the intervention. Therefore, it is important to evaluate if the trigger is igniting the behavior automatically as expected for that instance. However, the behavior influence can still lead to long-term effects through repetitive instances of influence (as shown in the project PianoTouch, which uses haptics for passive learning [29]).

2. Focus on Triggers

An issue of behavior change technologies that rely on the reflective mind (System 2) is that they often require users to be heavily motivated or have a strong ability to perform a behavior. In technologies based on System 1 processes, on the other hand, the reliance on user’s motivation and ability is smaller, since the behaviors can be triggered automatically. Therefore, triggers should be the main focus of designers of technologies based on System 1.

One important aspect to take into account when designing a mindless technology is that the trigger will be more effective if it is somehow embedded into people’s daily routines. In [55], the subjects were walking in the same environment that they would without the intervention, but with the presence of twinkly lights on the floor they were subtly influenced to take the stairs. With the Mindless Plate, users can serve their foods just like they would every day, but because of the lights triggering the Delboeuf illusion they can be subtly influenced to put less food than usual.

3. Parallel not serial

In order to achieve parallel functionality in a technology, the stimuli should be subtle enough so that the user does not have to think about the nudging feature. Therefore, instead of presenting information for the user to reflect, or reminding the user about a task to do, the technology should provide a simple trigger that influences the behavior of the user without distracting him from the current task. This can be attained in two ways. First, the trigger can be so subtle and covert that the user cannot perceive it. This kind of trigger can cause subliminal effects, affecting user’s behaviors even without being noticed. Second, the trigger can be overt and easily perceived, but the users do not realize that these triggers are affecting their behaviors. Both examples described in this paper fall in this category. In this last case, the cues act in the periphery, so users get attuned to them without attending to them explicitly [64].

One important consideration to achieve parallel functionality is that the mindless technology should not require any ad-ditional effort while the user is performing an activity. One way of accomplishing that is by providing a cue to the user that is not very different from what the user would normally experience in his daily life. For instance, in the mobile application designed to influence people's voice the user can hear his voice in a way that is very similar to what he normally hears. A loud voice feedback would attract attention to the technology itself, which would be very disruptive during social interactions. Another way of accomplishing this seamless integration with people's activities is by designing a technology embedded in an everyday object. In this case, the mindless technology should contain the same affordances as its non-technological counterpart. The Mindless Plate, for instance, can be used like a normal plate, without requiring the user to do something different from what he would normally do.

4. Don't ask, can't tell

Since System 1 works in an implicit an unconscious way, researchers can have problems to evaluate their technologies based on System 1. Users could change their behaviors without being aware of it, so the information obtained from interviews or surveys could be misleading. In [55], for instance, the authors had conflicting results with the displays deployed to encourage individuals to take the stairs instead of the elevator. While few people admitted changing their behavior in response to seeing the displays, the logged data showed a significant increase in the stair usage after the installation.

The contradictory result found in [55] could happen in any study based on a persuasive technology that relies on System 1. As discussed in [44], information perceived without conscious awareness can ignite implicit cognitive processes that the participant may not be able to discuss about. Therefore, researchers should be careful to draw conclusions based on information reported by participants. The participants can provide insights about the success of the intervention, but it is important to collect data in ways that does not rely entirely on participant's responses. For instance, in the voice influence study the voice of the participants was recorded and analyzed later to check if the pitch changed. In [2] the authors used sensors to detect when people used the water fountain.

CONCLUSION

Persuasive technologies have been designed and developed for several years. The large amount of studies involving the design and evaluation of these technologies have contributed to understand how to influence several kinds of behavior, such as practicing physical activities and eating healthier meals. However, many of the existing technologies were based on theories that put too much burden on the user. If the user is not conscious and motivated about a behavior to change, then the technology is likely to fail.

In this paper we show that there is another set of theories that can be leveraged to influence user's behavior requiring little or no user effort. We present a new approach for creating persuasive technologies that leverage these theories, Mindless Computing. These theories were created based on previous studies that show that human's mind has two operating systems: System 1(fast), which is automatic and unconscious, and System 2 (slow), which is conscious and works in a controlled way. After doing a systematic review of persuasive technologies presented at Ubicomp, CHI, Pervasive-Health and Persuasive we found that an overwhelming majority of the existing technologies rely on System 2 processes. In this paper we show how the focus on System 2 in the design of persuasive technologies has several limitations, that could be attenuated or even eliminated if System 1 processes are taken into account.

In order to show the feasibility of developing Mindless Computing technologies, we present two examples inspired by System 1 theories. The first example is the Mindless Plate, which uses perception bias to create the illusion that the portion of food on the user's plate is larger than it actually is. The second example leverages theories of subconscious speech influence and shows that it is possible to influence the user to change his average pitch during social interactions.

Finally, leveraging existing theories and the technologies developed to focus on the automatic mind (System 1), we provide a set of design considerations that can be used to guide the development of mindless technologies. In the future we plan to explore other modalities (e.g. vibration, ambient sound) in mindless technologies and test out the effectiveness through more extensive deployment. We hope the work presented in this paper will inspire others in designing persuasive technologies that take advantage of the automatic System 1 responses of individuals.

ACKNOWLEDGMENTS

This work has been partially supported by the following grants: NSF IIS #1202141 and NSF CBET #1343058.

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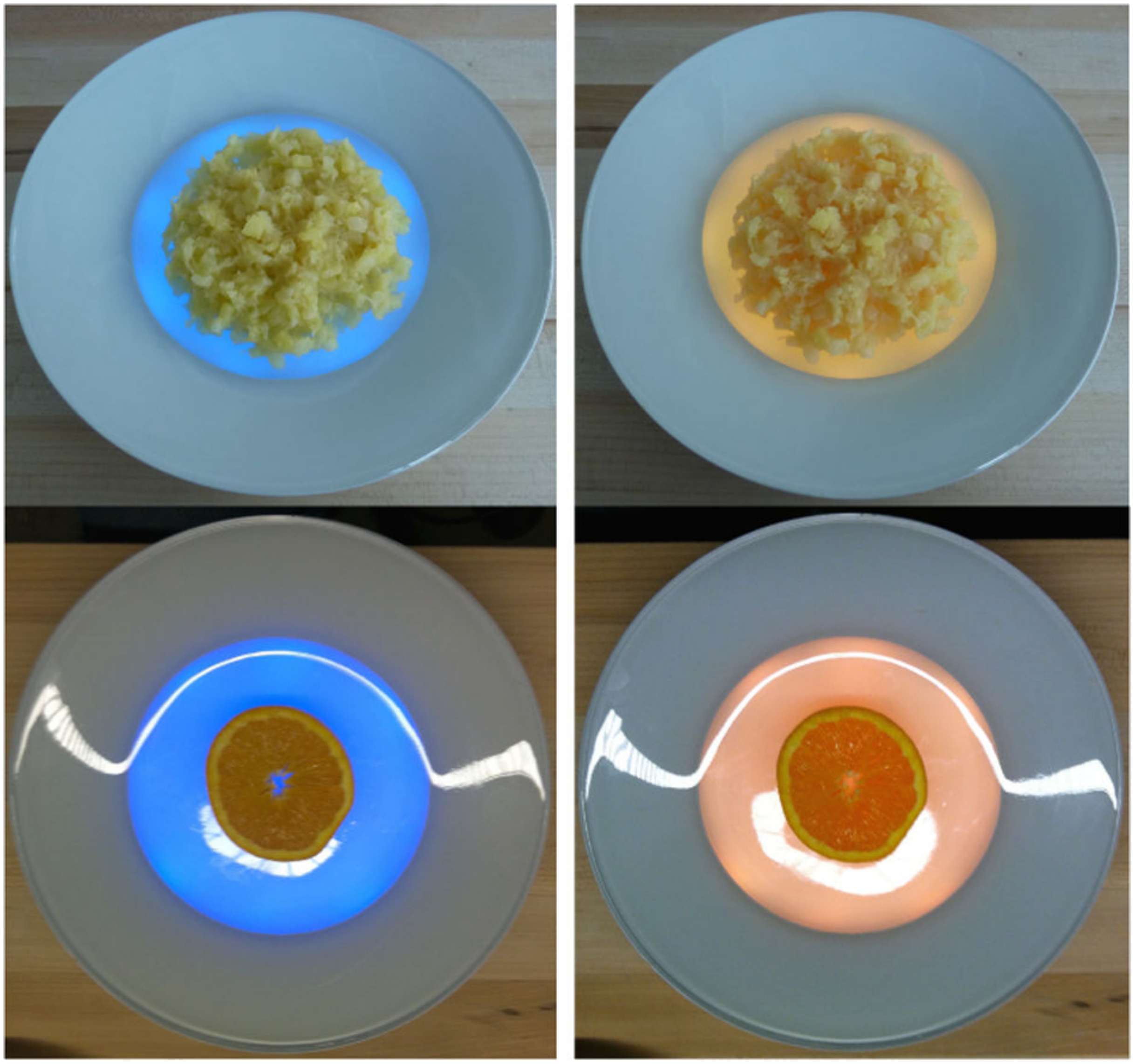

Figure 1.

Crushed pineapple (top) and a slice of an orange (bottom) on a Mindless Plate with a high and low contrasts in color

Figure 2.

Percentage of choices in both conditions (High and Low contrast) for all foods combined (probability of low contrast choice as measured by t-tests: p = 0.0011)

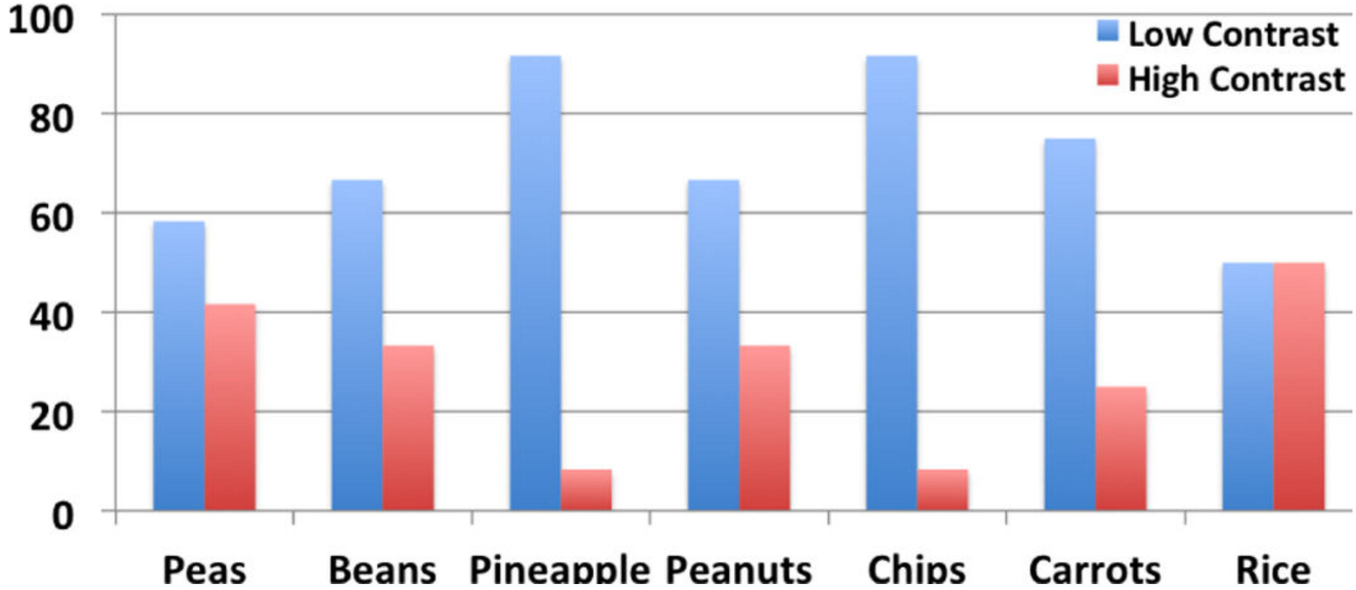

Figure 3.

The percentage of selections in each condition (High contrast and Low contrast) for each of the different foods used in the study

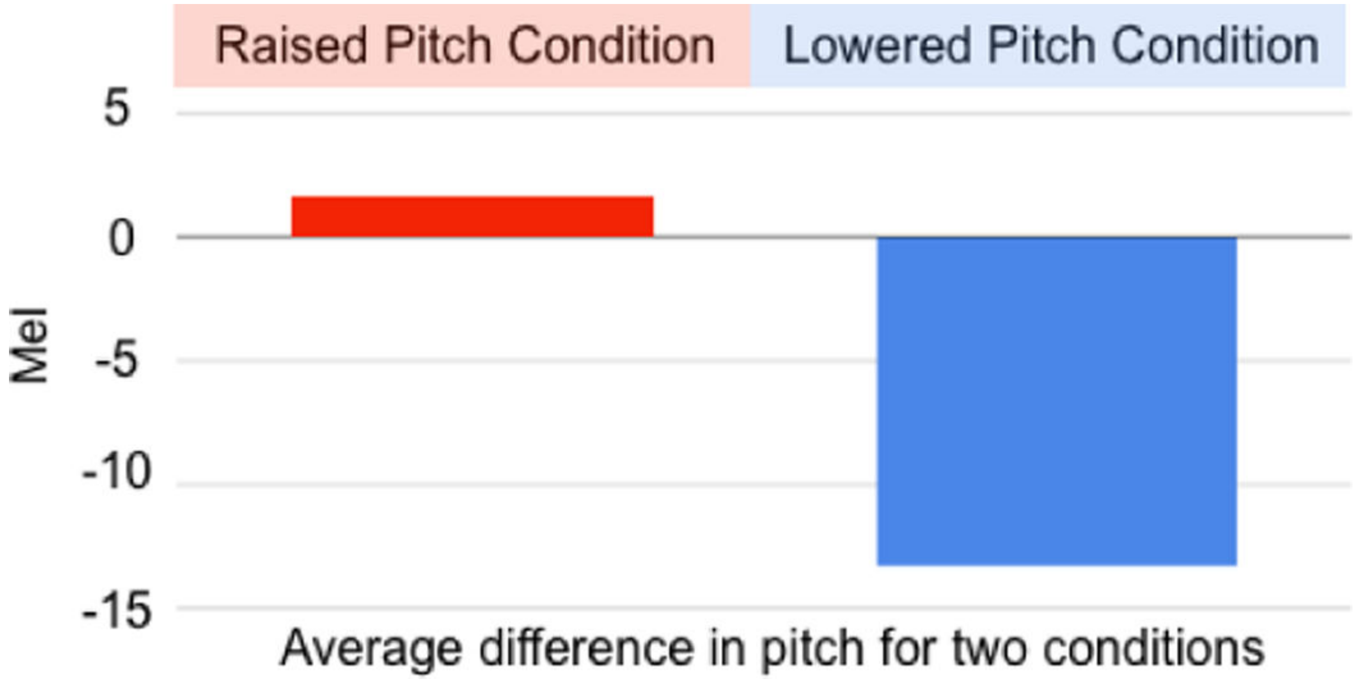

Figure 4.
Average change for both conditions (raised and lowered pitch)

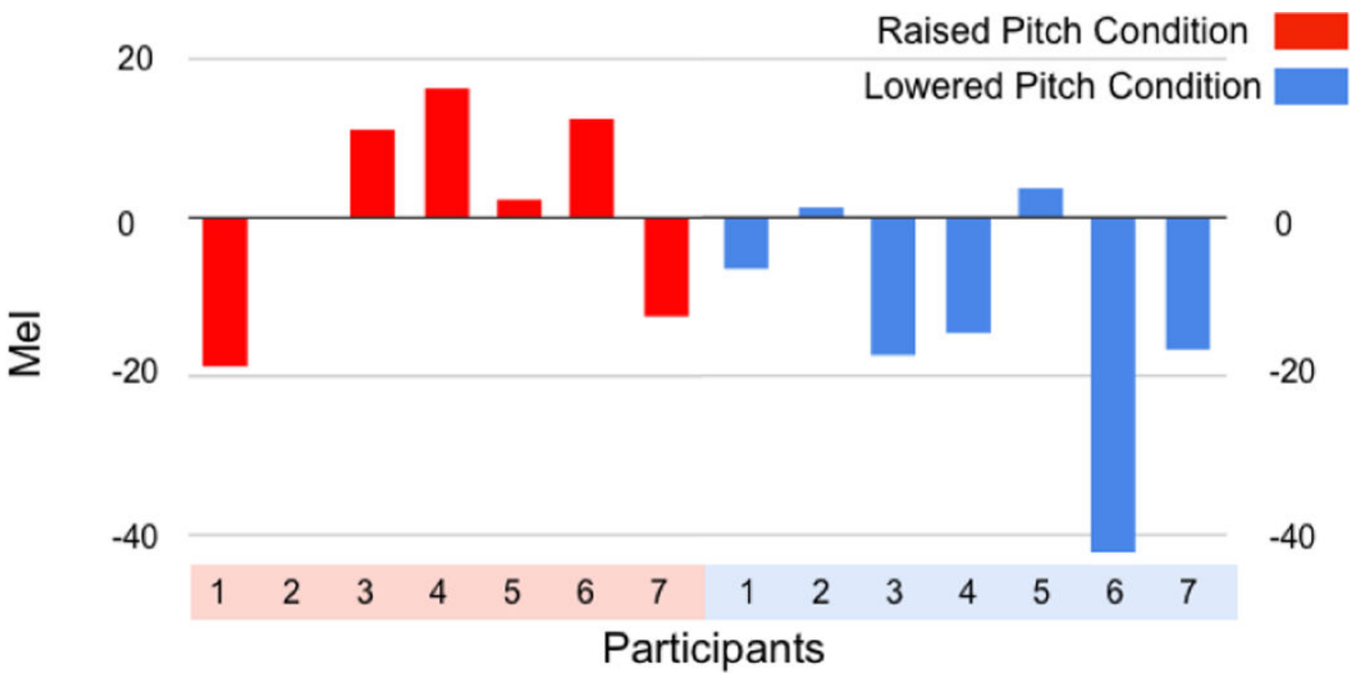

Figure 5.

Each participant's change in pitch from the baseline (7 participants for each condition)