Orecchio: Extending Body-Language through Actuated Static and Dynamic Auricular Postures

Da-Yuan Huang[1,2], Teddy Seyed[3], Linjun Li[1], Jun Gong[1], Zhihao Yao[1,4], Yuchen Jiao[1,4], Xiang 'Anthony' Chen[5], Xing-Dong Yang[1]

Dartmouth College[1], National Chiao Tung University[2], University of Calgary[3], Tsinghua University[4], University of California, Los Angeles[5]

{dayuan.huang; xiangchen}@acm.org, teddy.seyed@ucalgary.ca, {jun.gong.gr; xing-dong.yang}@dartmouth.edu

ABSTRACT

In this paper, we propose using the auricle – the visible part of the ear – as a means of expressive output to extend body language to convey emotional states. With an initial exploratory study, we provide an initial set of dynamic and static auricular postures. Using these results, we examined the relationship between emotions and auricular postures, noting that dynamic postures involving stretching the top helix in fast (e.g., 2Hz) and slow speeds (1Hz) conveyed intense and mild pleasantness while static postures involving bending the side or top helix towards the center of the ear were associated with intense and mild unpleasantness. Based on the results, we developed a prototype (called Orrechio) with miniature motors, custom-made robotic arms and other electronic components. A preliminary user evaluation showed that participants feel more comfortable using expressive auricular postures with people they are familiar with, and that it is a welcome addition to the vocabulary of human body language.

Author Keywords

Actuating human body, wearable earpiece, auricle, body language, emotion;

INTRODUCTION

Body language is an expressive means of non-verbal communication, and is used in more than 50% of daily conversations [47]. The old adage "actions speak louder than words" is continually applied in this context, where actions can include facial expressions, body postures, gestures, eye movement, touch [46], and is frequently used to express or convey non-verbal information (e.g., emotions or intention). Aside from everyday communication, body language (when paired with other approaches such as verbal methods) has many other important applications, from enhancing teaching skills [49, 54, 65] to perceiving

UIST '18, October 14–17, 2018, Berlin, Germany

ACM ISBN 978-1-4503-5948-1/18/10…$15.00
https://doi.org/10.1145/3242587.3242629

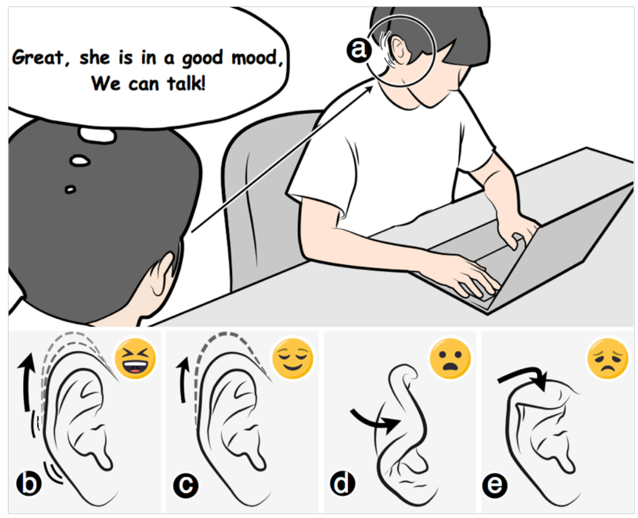

Figure 1. Auricular postures can be used in (a) situational impairment scenarios (e.g., concentrating on typing) to express emotions. This allows people to be socially aware before interruping. Our study found dynamic postures such as (b) stretching the top helix quickly (e.g., 2Hz) or (c) slowly (e.g., 1Hz) conveys intense and mild pleasantness. Static postures such as (d) bending the side helix and (e) bending the top helix convey intense and mild unpleasantness.

different clues in evidence that is critical to criminal and legal investigations [42].

One of the main limitations of body language is human anatomy, as only certain parts of the body can be used to meaningfully express body language – primarily the face, limbs, and hands. Furthermore, body language can also be impacted by different impairments, disabilities and handicaps. The relationships between these factors are complex, and can be affected by health conditions or context (i.e. tasks and environments) [58, 59]. Within the context of human computer interaction, this is referred to as *situational impairment* — where body function (and body language) is temporarily disabled, caused by a variety of factors such as divided attention, body motion, awkward postures, or encumbering tasks or objects [18]. These issues are further magnified for people with disabilities [29].

In this paper, we investigate the possibility of extending the vocabulary of human body language via the ear, an unused part of the body with limited mobility, but whose posture and movement has shown expressive meanings in other animals (e.g., cats, dogs, sheep, or cows) [3, 16, 55]. This inspired us to extend human body language using unused body parts with wearable technologies. Unlike prior work in the area to enhance the ear for input [33, 39, 48], we enhance the ear, specifically the *auricle* – the visible part of the ear – for expressive output. Our research mirrors the concept of human body augmentation, where technology enable humans to perform physical activities that we are unable to do naturally.

Applications

Using the auricle to extend body language can be useful in many situations. Our main objective is to explore new applications that can be enabled with this novel concept. For example, people with disabilities that involve severe impairment and the inability to use their face or limbs properly (e.g., those suffering from Amyotrophic Lateral Sclerosis), have difficulty expressing emotion. Using the auricle is one potential solution to allow for emotional expression or to enhance conversational flow with others, becoming a less obtrusive alternative to using a screen [35, 62]. As a body language, auricular postures can potentially be more natural and engaging than using a screen once accepted by the users. Moving the auricle also provide intrinsic haptic feedback to inform the user about auricular movements, which does not exist in a screen.

Furthermore, the auricle can also potentially increase *social awareness* of people before they engage a person who is temporarily (or situationally) impaired (e.g. eating, typing, diving, or wearing a face mask while performing a chore), leading to an improved ability to navigate and react to different social situations (Figure 1). In this context, the ear serves as an awareness display [67].

Finally, when combined with verbal methods or existing body language techniques (e.g. posture, touch, etc.), it can potentially provide richer and more expressive communication.

Contributions

Our primary contribution is a new type of body language using auricular postures, which we foresee inspiring future research in its varying applications.

At this early stage of research, with a number of technical and human perception questions, we focused on the fundamental question of how people perceive different types of auricular postures in relation to emotional states, one of the most common uses of body language [28]. We conducted a study using videos to elicit user agreement on emotional states of an initial set of 10 static auricular postures and 12 dynamic auricular postures (Figure 4), designed based upon an exploratory study. Results from 60 participants indicated that dynamic auricular postures involving stretching the helix (top part of the auricular) 2Hz and 1Hz are commonly associated with intense and mild pleasantness respectively (Figure 1b-c). Static auricular postures involving bending the side or top of the helix towards the center of the ear were associated with intense and mild unpleasantness respectively (Figure 1d-e).

It is also an important question to ask whether people are willing to use the auricle as a form of body language in varying social settings. To begin answering this question, we conducted an initial study to investigate the social acceptability for different actuation dynamics and usage contexts with a proof-of-concept prototype (called Orrechio), which we developed using miniature motors, custom-made robotic arms and other electronic components. Our results from 20 participants revealed that auricular body language is generally acceptable by today's users, but social acceptance currently relies upon the relationships with the people around them. For example, users were comfortable using auricular postures with people they were familiar with (e.g. friends), but less comfortable with those they were unfamiliar with (e.g. strangers). More importantly, observing others using auricular postures, regardless of relationship was overall socially acceptable by participants. This is very promising, indicating the potential of the wide adoption of auricular body language in the future.

BACKGROUND AND RELATED WORK

We briefly discuss the relevant background and prior work in expressing emotion and facilitating social awareness.

Body Language

Body language is an important aspect of non-verbal communication in everyday social life. It can be expressed through facial expressions, body postures, gestures, eye movement, or touch [46], and can be interpreted by the human brain very rapidly [43]. A central use of body language is to express emotion. Darwin once said that the emotions of humans or animals could be connected to their body language [10]. This was later proven to be true by years of scientific research, with studies showing that facial and body expressions can effectively convey emotional states [28, 45]. Aside from emotion, body language can also convey other internal states, such as intention or goal [28]. In everyday social scenarios, body language plays an important role in assisting social awareness and interactions, where emotions are expressed either consciously or unconsciously [11, 46].

While the ear is not a typical organ to express body language in the context of humans, animals commonly use the ear to express emotion (e.g., dog [24], cow [55], sheep [3], and rat [16]), to communicate with each other or to communicate with humans. For example, a dog owner can perceive that their dog's attention is focused if their dog leans their ears forward. Macaques — a primate species closely related to humans, is capable of adjusting the direction and the height of the auricle, or move it forward or backward, mainly for visual communication rather than acoustic aids [14].

Expressing Emotion through Technology

Existing research has shown that digital screens are widely used for expressing one's emotion, and primarily improving social awareness [7, 8, 62]. Understanding the emotional state of others allows for people to better interact with each other in different social situations. For example, conveying emotion using text, cartoon, iconic images has been shown to be effective in collaborative image browsing [9], programming [7], gaming [8], and helping people with Amyotrophic Lateral Sclerosis (ALS) to engage in one-to-one conversations [62]. Hassib *et al.* [25]'s system allows users to be aware of the emotional states of their long-distance partner, facilitating in developing relationships. Their system detects emotion using an EEG, which is conveyed to their long-distance partner whose body is actuated using electronic muscle stimulation (EMS). Aside from using brain waves for detecting emotions [38, 40], other sensing techniques include inferring emotion through facial expressions [37] and eye movement [4, 17]. See [6] for a comprehensive review of the technologies for emotion sensing and its wide variety of applications. We separate our work from existing research by focusing on a new form of expressing emotions. We actuate the ear itself, in a similar manner to how body language is already used for non-verbal communications.

Display Technologies for Social Awareness

Our work is also related to research exploring the use of public displays for showing personal information (e.g., emotion) to enhance social awareness [20]. One example is to use ambient light to inform people nearby about a person's mood, thereby allowing them to adjust their social strategy [61]. Similarly, light effects can be used to show the availability of the person to largely reduce interruption at work [2, 70]. One major limitation of the public display technique is mobility, as the technology cannot be readily used in mobile situations.

With rapid developments in wearable technology, on-body displays have been adopted for use as public displays to show personal information in mobile situations. Examples include using a smartwatch to display the wearer's schedule for nearby people so that in situations, where the wearer is unaware of an upcoming event (e.g. an appointment), the glancer can remind the wearer [51]. Other form factors for public displays that aren't smartwatch include an array of screens worn on the forearm [50], wristband [30], clothes [27, 44, 66], helmet [69], and shape-changing jewelry [15].

One major issue of a wearable screens is that they can be obtrusive if worn on an unusual part of the body, such as the ear. Thus, several areas of research have explored wearable display technologies on the body, without using a computer screen. For example, changing the color of one's makeup [32] or clothes [12], have been used in applications for enhancing self-expression. Changing the shape of an earring has also been used to show the current app use state of the wearer [15]. The physical shape and appearance of personal clothing can also be dynamically changed using a robot that crawls on the body to show personal information to nearby people [31]. Body-worn mechanical tails and ears have also been used to improve performance of actors on stage [64]. Hint [26] improves social awareness through a clothing-based display, showing the wearer's arousal changes via color patterns. Finally, Necomimi [13] is a commercial head-worn device in the shape of cat ears that can change their shape, to publicly display the wearer's emotion detected using brainwave signals. Due to the inadequate bandwidth, information conveyed by these approaches are often quite limited.

In this research, we focused on developing an initial wearable technology that can actuate the unused auricular to express emotion in a number of scenarios involving impairment, where body language cannot be performed.

THE HUMAN EAR

The human ear is the primary organ used for hearing. It consists of the outer, middle, and inner ear. The visible part of the ear is the *auricle* (Figure 2), which is mainly composed of muscles and cartilage that can be stretched, bent, or twisted without causing much discomfort to a person. This makes it a suitable candidate to perform physical expressions using the body. Another benefit of using ear posture to convey non-verbal information, is that when deformed, the ear can provide natural haptic feedback. This is missing in many other candidates available on the body (e.g., hair).

The musculature of the human ear is generally not strong enough to make significant ear movements, despite some people being able to move their ears. As such, humans have very limited use of the ear as a part of body language to convey information. Many of them involve using the hand [5]. For example, tugging at the earlobe can be used to show that a person is trying to block the words he is hearing, an adult version of hands covering both ears used by children who do not want to listen their parents' reprimands. Furthermore, grabbing the ear can also be a signal that a person is anxious [52]. Our research aims to extend existing physical expressions using the ear by exploring the emotion states that can be conveyed through actuation of the ear.

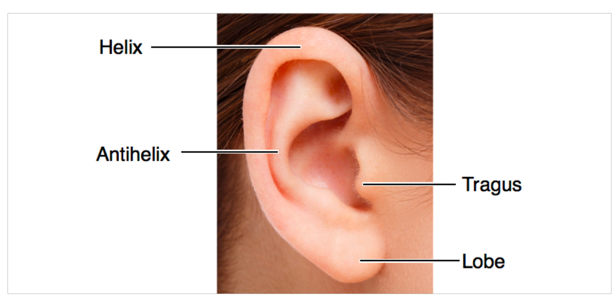

Figure 2. The structure of the auricle. Helix and lobe are the most visible.

EXPLORATORY STUDY: ELICITING AURICULAR POSTURES

Among the different parts of the ear, the auricle is the most visible to people in close proximity. The auricle is also soft and flexible, allowing several ways for it to be moved or manipulated. We conducted an exploratory study to explore and elicit different auricular postures and movements, specifically focusing on the physically comfort when they are being performed. Note that our aim is not to explore the postures for output, but to understand what deformations with the auricle are physically comfortable to perform.

Participants and Task

We recruited 10 right-handed participants (4 female, aged 23-25) to participate in the study. As interpretation of body language varies differently from culture to culture [34], we recruited participants from the same cultural background (China). The procedure was similar to the one used in [60], where participants were asked to propose different auricular postures and movements they felt physically comfortable to perform. Participants were not told the purpose of the postures, and they were encouraged to propose as many as possible, demonstrating their ideas using their right ear. Our aim was not to create an exhaustive list of postures through elicitation, but instead to uncover auricular techniques people are comfortable with, and an initial set of postures to explore in relation to different emotional states.

Results

The results revealed that the helix and earlobe are the most common locations to deform the auricle. For example, 72.5% of all proposed postures involved the top helix (25%), the side helix (25%), and the earlobe (22.5%) (Figure 3a). In terms of deformation, stretching or bending the auricle were the most common ones with 42.11% of the proposed postures involving stretching and 36.84% of them involving bending (Figure 3b). For stretching, a majority of participants suggested stretching the top of the helix or its side. Stretching the earlobe was also common. For bending, participants proposed to bend the top of the helix, the of the side helix, or the earlobe towards the center of the ear. Aside from these common postures, participants also proposed to press the auricle (Back-fold), twist the auricle (Twist), press the earlobe upwards (Squeeze). These proposed postures were all visually distinguishable from each other and from the auricle in its natural position. None were considered uncomfortable to perform by participants. We used the six most common ones (e.g., stretching / bending top helix, side helix, and earlobe) as "primitives" to design our auricular postures.

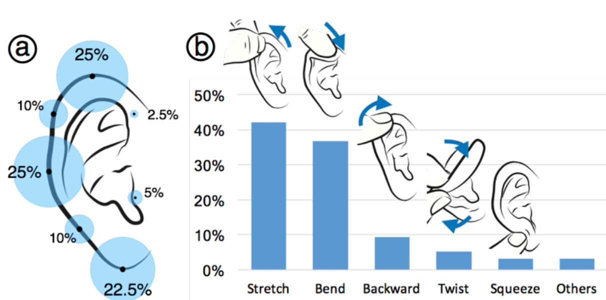

Figure 3. (a) Common places to deform the auricle; (b) Percentage breakdown of the proposed auricular gestures.

AURICULAR POSTURES

From our initial exploratory study, we designed 22 auricular postures based on the six "primitives" we observed (Figure 4 a-c, e-g). Our designs include both static (10) and dynamic postures (12), commonly used in body language researches [1, 21, 57, 68]. Our list is not exhaustive, but the gestures provide enough diversity for us to begin studying the relationship between auricular postures and emotions.

Static Postures

With static postures, the auricle is deformed and remains stretched or bent until released.

Stretch/Bend Top Helix (S). The top of the helix is stretched upwards (Figure 4a) or bent downwards (Figure 4e). We use "(S)" to indicate it is a static posture.

Stretch/Bend Side Helix (S). The side of the helix is stretched sideward (Figure 4b) or bent towards the center of the ear (Figure f).

Stretch/Bend Earlobe (S). The earlobe is stretched downwards (Figure 4c) or bent upwards (Figure 4g).

Different postures can also be combined to form new types of static postures.

Stretch All (S). This static posture is the combination of *Stretch Top Helix (S)*, *Stretch Side Helix (S)*, and *Stretch Earlobe (S)* (Figure 4d).

Bend All (S). This static posture is the combination of *Bend Top Helix(S)*, *Bend Side Helix (S)*, and *Bend Earlobe (S)* (Figure 4h).

Stretch Earlobe & Bend Top Helix (S). This static posture is the combination of *Stretch Earlobe (S)* and *Bend Earlobe (S)* (Figure 4i).

Stretch Top Helix & Bend Earlobe (S). This static posture is the combination of *Stretch Top Helix (S)* and *Bend Earlobe (S)* (Figure 4j).

Dynamic Postures

Dynamic postures are similar to their static counterparts, but the postures remain moving (or animated) until they are released. Our design includes all six simple postures, including *Stretch/Bend Top Helix (D), Stretch/Bend Side Helix (D),* and *Stretch/Bend Earlobe (D)*. We use "(D)" to indicate it is a dynamic posture. We also include several combined postures.

Stretch Top Helix & Earlobe (D). This dynamic posture occurs with *Stretch Top Helix (D)* and *Stretch Earlobe (D)* happening simultaneously (Figure 4n).

Top & Earlobe Up → Top & Earlobe Down (D). This dynamic posture first begins with *Stretch Top Helix (D)* & *Bend Earlobe (D),* followed by *Bend Top Helix (D)* & *Stretch Earlobe (D),* and then repeats (Figure 4r).

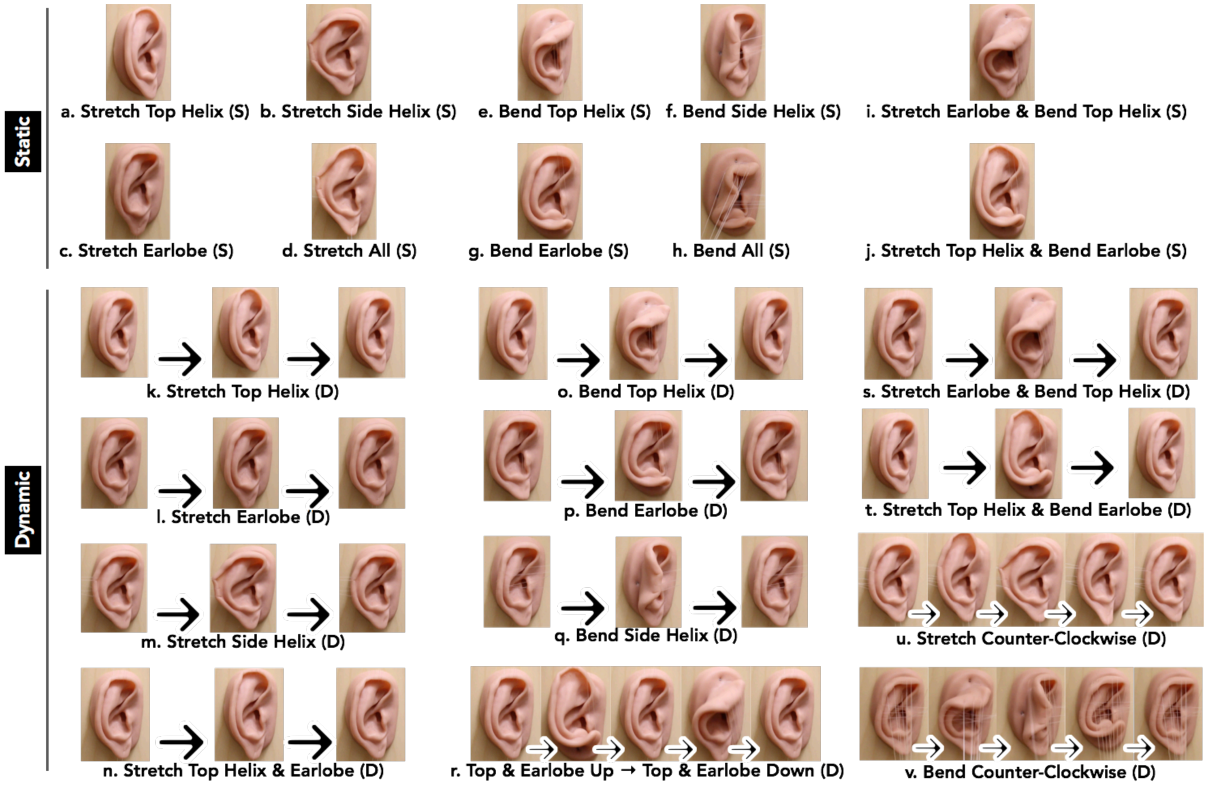

Figure 4. The static and dynamic auricle postures used in Study 1. The dynamic postures start and end with the ear in its normal shape.

Stretch Earlobe & Bend Top Helix (D). This dynamic posture occurs with *Stretch Earlobe* and *Bend Top Helix (D)* happening simultaneously (Figure 4s).

Stretch Top Helix & Bend Earlobe (D). This dynamic posture occurs with *Stretch Top Helix (D)* and *Bend Earlobe (D)* happening simultaneously (Figure 4t).

Stretch Counter-Clockwise (D). This dynamic posture loops *Stretch Top Helix (D)* → *Stretch Side Helix (D)* → *Stretch Earlobe (D)* in a counter-clockwise order (Figure 4u).

Bend Counter-Clockwise (D). This dynamic posture loops *Bend Top Helix (D)* → *Bend Side Helix (D)* → *Bend Earlobe (D)* in a counter-clockwise order (Figure 4v).

STUDY 1: EXPRESSING EMOTION

The goal of this study was to measure how people perceive auricular postures in relation to emotional states. We were particularly interested in learning if a general agreement existed between people when interpreting certain auricular postures.

Video Prototype

Only the ear is shown in the video to simulate the scenario where other parts of the body are unavailable/incapable for expressing body language. Isolating the desired body part is also a common approach in studying body language [21, 63]. We chose to use the concept video approach as prior work has shown it to be successful in evaluating futuristic concepts such as shape-changing phones [53]. Videos also allowed our study to be highly controlled as participants saw the same physical demos.

Protocol

Our study protocol is similar to [22, 23], where participants were shown 23 auricular postures, one at a time, and asked to rate their agreement with their interpretations about the emotional states from a list of 16 emotions, well spread from Russell's circumplex model of affect [36, 56] (Figure 5). For example, *Delighted, Happy, Excited,* and *Astonished* were picked from the top-right section; *Serene, Calm, Relaxed,* and *At East* were picked from the bottom-right section; *Tense, Distressed, Angry,* and *Afraid* were from the top-left section; and *Sad, Depressed, Tired,* and *Bored* were from the bottom-left section. The scores were given in a 5-point continuous numeric scale with 1 representing strongly disagree and 5 strongly agree. Participants could watch the videos as many times as they wanted. After the 16 emotions had been rated with respect to the auricular postures, the next posture appeared in a random order. A semi-structured interview was performed at the end of the study.

Participant

We recruited 60 participants (30 females) for the study, aged from 19 to 31 years. All participants were from China.

Results

Study results were analyzed using one-way ANOVA. Violations to sphericity used Greenhouse-Geissers to the degree of freedom. For each auricular posture, an ANOVA test yielded a significant effect of emotional state on user agreement scores (all $p < .05$ except BendEarlobe(S) with $p=.055$), indicating that some emotional information can be conveyed better using certain auricular postures rather than others.

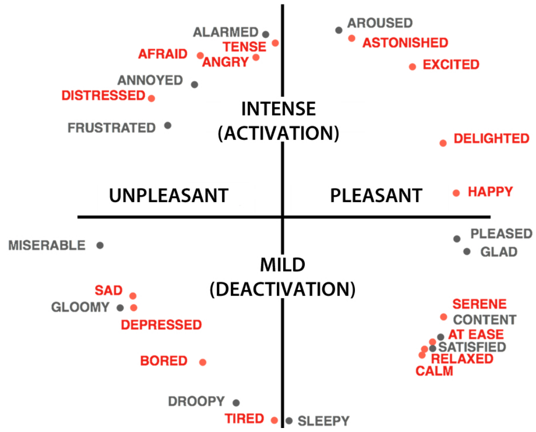

Figure 5. Emotions plotted on the circumplex model of affect. The ones used in the Study 1 are highlighted in red.

We then conducted a factor analysis on the ratings of 22 emotional states using Maximum Likelihood and Varimax rotation. The result showed a KMO of 0.871 with Bartlett's test of sphericity being significant ($p < .005$), indicating that groups of the auricular postures are highly correlated. Digging deeper into the data revealed that four primary components had eigenvalues greater than one and explained 65.84% of total variance, suggesting that there are four categories of postures being highly correlated. Table 1 shows the four categories and their corresponding emotional states. This is consistent with the grouping of Russell's circumplex model of affect [56] shown in Figure 5. This is an encouraging result, indicating that auricular postures alone can be expressive enough for conveying emotional states at a high level. We named these categories Intense Pleasantness, Mild Pleasantness, Intense Unpleasantness, and Mild Unpleasantness.

Category	Emotional States
Intense Pleasantness	Delighted, Happy, Excited, Astonished
Mild Pleasantness	Serene, Calm, Relaxed, At East
Intense Unpleasantness	Tense, Distressed, Angry, Afraid
Mild Unpleasantness	Sad, Depressed, Tired, Bored

Table 1. The four categories extracted from the factor analysis.

The next step was to identify the set of postures that can best represent the four emotional categories using a mixed model analysis. For each posture, the corresponding agreement scores of the 16 emotional states were divided into the four emotional categories. The candidate postures for a certain emotional category were identified by those scoring high on user agreement (e.g., > 3.5) in one emotion category but low (e.g., < 3) in the other categories (e.g., minimal ambiguity between the categories). In total, seven postures met our criteria, which we report in each category.

Intense Pleasantness

Five auricular postures received agreement scores higher than 3.5 (e.g., *Stretch Top Helix (D), Stretch Counter-Clockwise (D), Stretch Top Helix & Earlobe (D), Stretch Top Helix & Bend Earlobe (D),* and *Bend Earlobe (D)*)

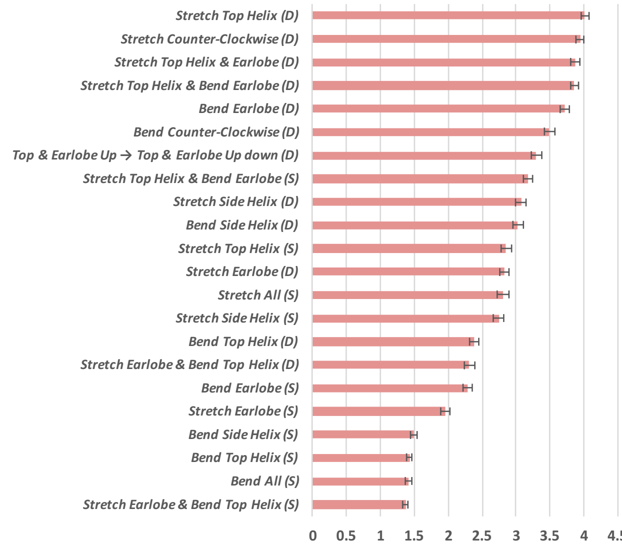

Figure 6. Agreement scores of the auricular postures in the Intense Pleasantness category. Error bars show ± 1 SE in all figures.

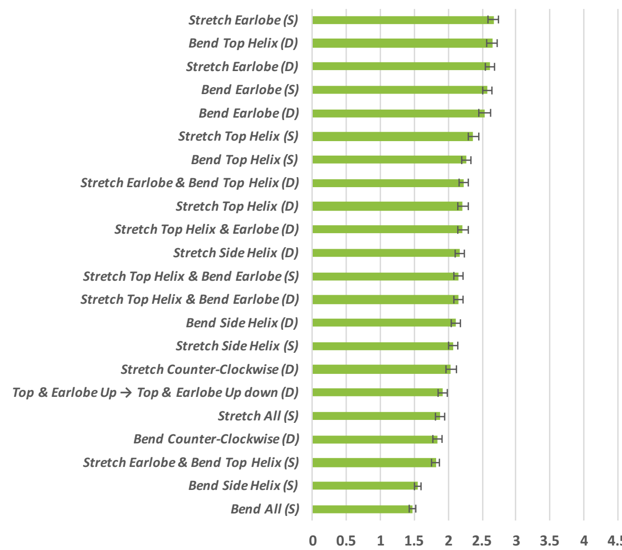

Figure 7. Agreement scores of the auricular postures in the Mild Pleasantness category.

(Figure 6). Their scores are also significantly higher than the rest of the postures (all $p < 0.5$). None scored higher than 3 in the other categories, indicating a strong one dominant interpretation. These postures are all dynamic postures, four of which involve stretching the top of the helix. Interestingly, most of the static postures scored low (e.g., < 3). Our interviews revealed that participants considered static postures "*give a negative feeling*" (P3, P7), and are thus unrelated to positive emotions.

Mild Pleasantness

None of the auricular posture scored higher than 3 in this category (Figure 7). Participants interpreted the auricular posture differently regarding their emotional states. Interviews with participants suggested that more people considered it natural to use dynamic postures to indicate mild pleasantness, but the speed of ear movement itself was too fast to be related to “mild”. This is an interesting result, as it indicates that the speed of the auricular motion may play an important role in interpreting emotional states. We investigated the effect of speed in a follow-up study.

Intense Unpleasantness

Only one auricular posture (e.g., *Bend Side Helix (S)*) scored higher than 3.5 in this category and lower than 3 in the other categories. The agreement score of this posture also significantly outperformed the other auricular postures (all $p < 0.05$). This posture was static, suggesting that showing the auricle bent from the side can be related to the intense unpleasantness of a person. Participants’ comments confirmed that the auricle bent towards the center of the ear displayed a negative emotion. Interestingly, the dynamic bending postures did not deliver the same interpretation (Figure 8). This is because looping the posture unbends the auricle from its deformed position (before it can be bent again), and the unbend motion was not interpreted as a negative emotion.

Mild Unpleasantness

One auricular posture received an agreement score higher than 3.5 in this category (i.e., *Bend Top Helix (S)*) and lower than 3.0 in all other categories (Figure 9). It also scored significantly higher than the rest of the postures (all $p < 0.5$). Similar to the Intense Unpleasantness category, the auricular postures in this category were also static. Our interviews revealed that participants associated bending the auricle downward to mild negative emotions. This is an interesting finding, as it suggests that emotional states are associated with the direction in which the auricle was bent, which may explain why *Bend Earlobe (D)* (upwards) was

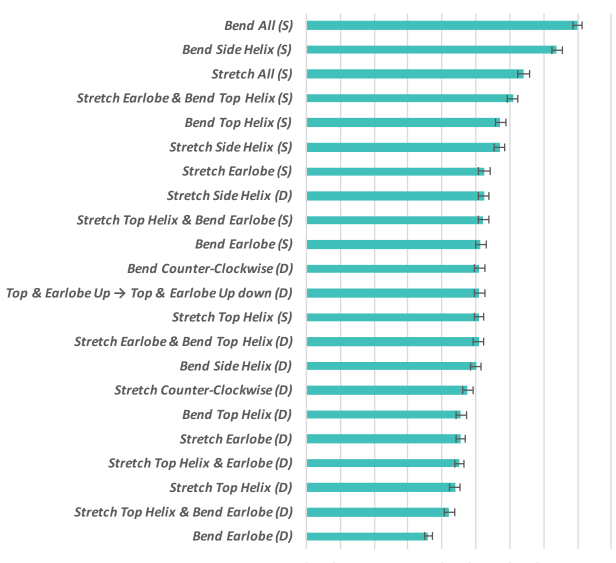

Figure 8. Agreement scores of the auricular postures in the Intense Unpleasantness category.

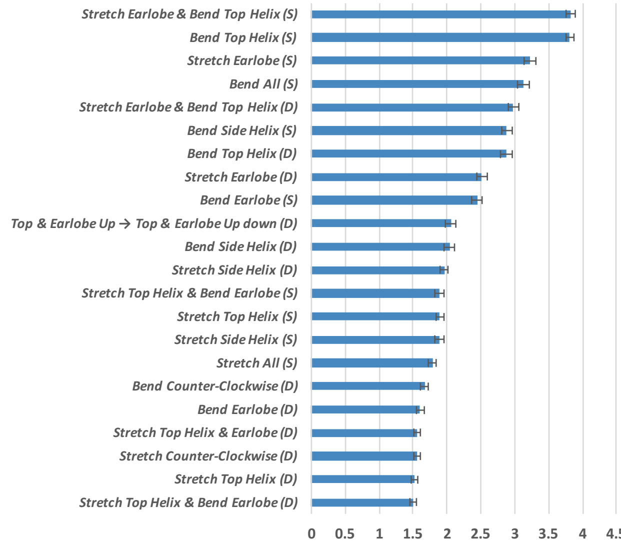

Figure 9. Agreement scores of the auricular postures in the Mild Unpleasantness category.

deemed as a positive emotion (e.g., intense pleasantness).

Speed Effect

To understand how the speed of dynamic postures may affect people’s interpretation of emotional states, we conducted a follow-up study with 20 new participants (9 female, age 21-30), where we asked them to give agreement scores on dynamic postures shown in its original speed (2 Hz), half spseed (1 Hz), and double speed (4 Hz). The procedure of the study was the same as the previous one.

A repeated measures ANOVA with Greenhouse-Geisser corrections showed a significant effect of Speed ($F(1.94, 1861.43)=70.43$, $p<.001$) and Emotion ($F(2.69, 2576.37)=283.18$, $p<.001$), and an interaction effect on Speed x Emotion ($F(5.14, 4932.62) = 846.22$, $p<.001$). For each of the four categories of the emotion state, we further performed a one-way ANOVA using speed as an independent variable, which yielded significant differences of speed for all the emotional categories (all $p < 0.05$). Post-hoc analysis revealed that for most postures, the agreement scores of the two mild emotions (e.g., Mild Pleasantness and Mild Unpleasantness) increased when the posture speed decreased ($p < 0.05$ for 91.6% of the postures), while the agreement scores for the two intense emotions (e.g., Intense Pleasantness and Intense Unpleasantness) increased with an increase of speed ($p < 0.05$ for 70.8% of the postures) .

In general, participants considered postures in a slower motion more related to Mild Pleasantness. Among the 12 postures, four of them (e.g., *Stretch Top Helix (D), Stretch Side Helix (D)*, *Bend Side Helix (D), and Bend Earlobe (D)*), received agreement scores higher than 3.5 in the Mild Pleasantness category, while below 3 in the others. Increasing the speed of the motion shifted the agreement from Mild Pleasantness to Intense Pleasantness. This is consistent with the result of the main study as participants related the speed of the postures to the level of the positive emotions. Note that agreement scores for the negative emotions may also increase with the change of speed. However, dynamic postures are in general poorly related to negative emotions, especially those ranked high for Intense Pleasantness (e.g., < 3). This is also consistent with the result from our main study. Therefore, we expect it is unlikely for people to misinterpret the meaning of a dynamic posture.

Discussion

Our study revealed several interesting findings. First, the dynamic auricular postures were more inclined to convey positive emotions whereas the static auricular postures tended to convey negative emotions. Intense pleasant emotions can be expressed by stretching the top helix repeatedly with a frequency of around 2 Hz or higher. Reducing the speed of this posture to around 1 Hz conveys mild pleasantness as participants related speed with the level of pleasantness. Negative emotions can be expressed using a static auricular posture by bending the helix. Participants associated the level of a negative emotion to the direction of bending. For example, bending the side helix towards the center of the ear was considered more intense (e.g., Intense Unpleasantness) than bending the top helix downwards (e.g., Mild Unpleasantness). These findings suggest that emotions like intense / mild pleasantness and intense / mild unpleasantness, can be conveyed by simply stretching or bending the helix. We applied these findings to the design of our wearable prototype, described in the next section. The effect of untested speeds and postures warrants further investigations.

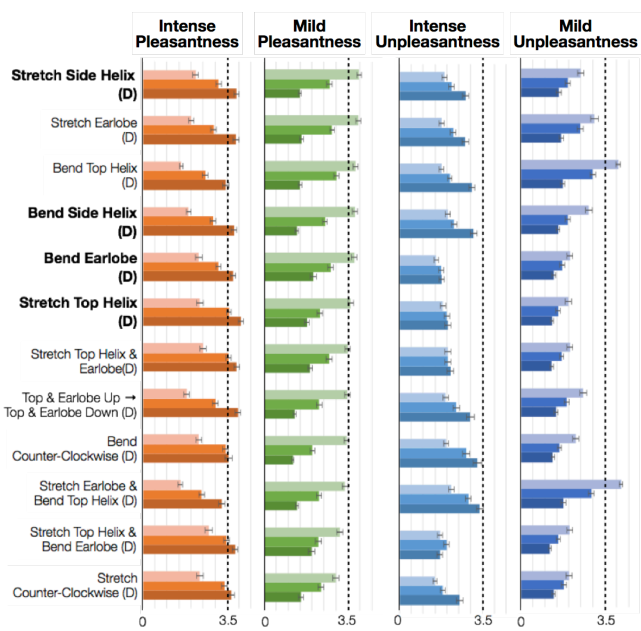

Figure 10. Agreement scores of the dynamic postures. Speed is indicated by color brightness – the darker the faster.

ORECCHIO PROTOTYPE

To access the social acceptability of auricular body language and demonstrate technical feasibility, we developed a proof-of-concept prototype earpiece (Figure 11), able to stretch and bend the top and side of helix. The prototype was implemented using off-the-shelf electronic components, miniature motors, and custom-made robotic arms. The device has a micro gear motor (Firgelli AD-DMC3198-F-3 DC Motor) mounted on the bottom of a 3D printed ear hook loop clip (Figure 11a). The motor drives a plastic arm against the side of the helix, able to bend it towards the center of the ear (Figure 11d). Rotating the plastic arm back to its rest position allows the helix to restore to its original form. Near the top of the earpiece is another motor (Micro Planetary Reducer Motor Dia 10MM) that drives a one-joint robotic arm that is attached to the top of the helix, using a round ear clip. Rotating the motor extends the robotic arm from its resting position, to bend the top helix downwards the center of the ear (Figure 11e). The motor together with the one-joint robotic arm is mounted on a linear track that can be moved vertically through a rack-and-pinion mechanism, driven by a third motor. Moving the rack upwards stretches the helix (Figure 11c).

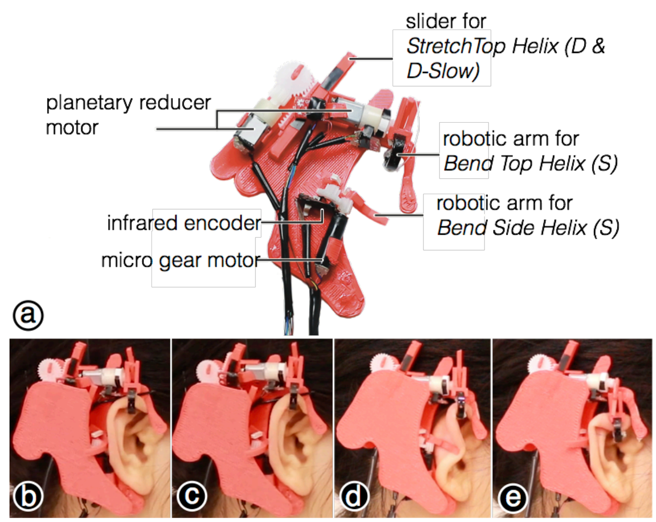

Figure 11. (a) The structure of Orecchio prototype. (b) Auricle in its normal shape; (c) stretch top helix; (d) bend side helix; (e) bend top helix.

We used infrared analog encoders (QRE1113 from SparkFun) to provide position feedback for the rack and the motors driving the robotic arms. The earpiece weighs about 23.8g, and can be worn comfortably on the right ear. The motors are connected to a DRV8835 motor driver board, connecting to an Arduino DUE microcontroller along with IR encoders. The Arduino is then connected to a Windows laptop using a USB cable, with a custom C# application controlling actuation remotely. The prototype is larger than we envision for a real device, but it is effective for demonstrating the concept and exploring the social acceptability of auricular postures. Implementing an emotion sensor is not the focus of this work but we envision that emotion sensing through the ear (e.g., [19]) can be integrated into our device in the future.

STUDY 2: SOCIAL ACCEPTABILITY AND COMFORT

The goal of this study is to assess social acceptability and device comfort for different auricular postures and usage contexts.

Participants

Twenty new participants (7 female, aged 20 to 28) were recruited. All participants were from China.

Protocol

Participants completed the study in a local café to simulate a social environment, with an average visitor flow of 48 persons per hour. Prior to the study, they rated the degree of field publicity (average = 3.86; s.d. = 0.55) on a 5-point Likert Scale (1 means very private, 5 means very public). During the study, we tested the social acceptability of four auricular postures in a fixed order, including *Stretching Top Helix (D)*, *Stretching Top Helix (D - Slow)* (e.g., 1 Hz), *Bend Side Helix (S),* and *Bend Top Helix (S)*. The postures represent Intense Pleasantness, Mild Pleasantness, Intense Unpleasantness, and Mild Unpleasantness respectively. The study was conducted in a sitting position, where participants wore the prototype on their right ear. They were free to view their ear movement in a mirror or through a live video filmed by an experimenter (Figure 12). Participants were specifically asked to rate the social acceptability of the postures rather than the device. They were informed that the hardware would be miniaturized in the future and it was understood that the device was meant to provide functionality and facilitate imagination and was not a final prototype or product.

For each auricular posture, participants answered a series of questions regarding the acceptability of the posture in varying social situations. First, participants were asked to imagine using the auricular postures in the presence of different people. They answered yes-or-no regarding which audience(s) ("Partner", "Family", "Friends", "Colleagues", "Strangers") they would feel comfortable with while the auricle moved to a posture. They also answered yes-or-no indicating whether they would be bothered by the auricular posture used by a member the same audience. Finally, participants also rated the comfort of our device in generating each auricular posture using a 5-point continuous numeric scale.

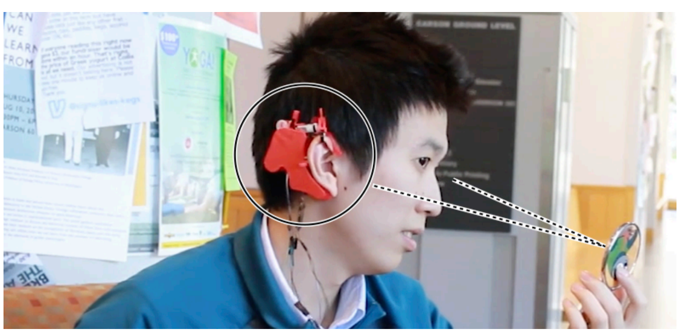

Figure 12. A participant looking at an auricular posture using a mirror in the social acceptability study.

Results

Participants' yes-or-no responses were analyzed using Cochran's Q test with McNemar's test for pairwise comparisons. Significance levels were adjusted using Bonferroni's correction when multiple tests were taken. Device comfort ratings were analyzed using one-way ANOVA. Violations to sphericity used Greenhouse-Geisser corrections to the degrees of freedom. Post-hoc tests used Bonneferoni corrections for multiple comparisons.

Social Acceptance

What's promising is that most participants expressed some level of acceptance of using the auricular postures in a public setting. However, the answers for the question "With whom you are willing to use auricular postures?" was significantly affected by *Audience* ($\chi^2(4) = 176.127$, $p < 0.001$) and *Posture* ($\chi^2(3) = 25.209$, $p < 0.001$). Figure 13 illustrates the results.

Post-hoc analysis showed significant differences between all pairs of audiences (all $p < 0.05$) except partner and family ($p = 0.5$). Partner was rated the highest amongst all participants (95%). The acceptance rate decreases when the level of familiarity to the audience decreases (e.g. stranger). Aside from family and partner, more than 75% of our participants considered it acceptable to use auricular postures in front of friends. A participant commented that "*auricular postures are pretty much like eye contact with a friend" (P5)*. On the other hand, around half of our participants felt reluctant about using auricular postures in front of colleagues. They were concerned that moving the auricle "*does not seem professional" (P4, P19)* as the auricular postures can sometimes be "*too cute" (P7)*. In contrast, another half saw themselves using auricular postures, especially during situational impairment situations. Participants commented that *"I see auricular postures can be a useful addition to the existing ways of communicating in the workspace" (P2, P18).* Therefore, we foresee that people will primarily use Orecchio at home or in the workspace, at least in its early adaptation.

More than 90% of our participants felt reluctant about using auricular postures in front of strangers, as they felt it would be socially awkward to show ear movements to people they do not know. However, one participant stated that "*I don't mind the strangers since they don't know who I am" (P8).* Amongst all postures, participants were more concerned about using *Bend Side Helix (S)* than the other postures (all $p < 0.001$), notably in front of strangers. There was no significant difference among the scores of the other three postures (all $p > 0.05$). With *Bend Side Helix (S)*, participants considered the amount of auricular movement "*a bit too much to show in front of people" (P20).* This is interesting as it suggests a direction for future research to study the balance between posture subtlety and clarity. More importantly, participants expressed the need to have control over the device (e.g., turn off when needed). They wanted to control when, where, and to whom their emotions were revealed.

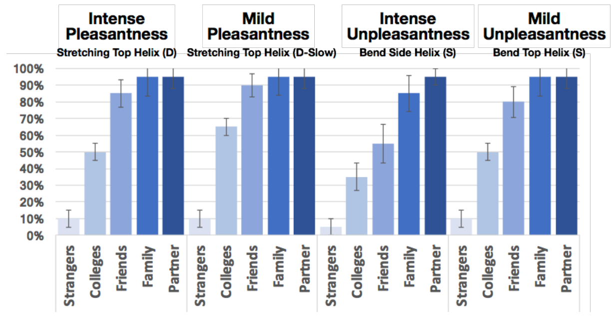

Figure 13. Acceptance rates shown by Audience and Postures.

For the question "Are you bothered if you see these people use the auricular postures?", there was no significant difference in *Audience* ($\chi^2(4) = 8.970$, $p = 0.062$) but there was a significant difference in *Posture* ($\chi^2(3) = 26.831$, $p < 0.001$). More than 80% of our participants considered it acceptable to see other people using auricular postures, which may eventually encourage people to use Orecchio in front of strangers. This is interesting, showing that people feel much more social pressure when using auricular postures themselves. Note that such social pressure may come from the cultural background of our participants and may vary from culture to culture [41]. Overall, our result suggests there is a potential of wide adaptation of auricular body language in the future.

Device Comfort

A one-way ANOVA showed no significant differences between postures ($F_{2.25, 42.7} = 1.718$, $p = 0.18$). Our device was given an average score of 3.8 (with 5 being extremely comfortable) on the level of comfort. No participants reported discomfort during the use of the device. The surface of some 3D printed parts (e.g., ear hook and robotic arms) felt a bit rough and can use some extra smoothing or be replaced with soft rubbery materials. Overall, participants agreed that our prototype was relatively comfortable to wear and use.

LIMITATIONS AND FUTURE WORK

Implementation. The device is bulky in its current implementation, and the hearing of a wearer may be interfered with by motor noise during usage. We envision that technology developments will allow us to create devices that are smaller, quieter, less obtrusive, more comfortable to wear, or may eventually become invisible. For example, replacing motors with shape-changing alloy can reduce the device size and noise effectively.

Comfort. Although our participants did not inform us about any negative impacts from motor noise, ability to hear, or physical discomfort, these potential factors require careful, long-term studies as future works. Additionally, new sensors can be developed to detect people's presence near the user. This allows the auricular postures to be shown only if they can be seen by other people.

New dimensions and use cases. Actuating the human body for communication warrants careful future research. In our work, we only explored auricular postures for conveying emotional information. Auricular postures can also be used as an output for the wearer, beyond informing auricular movements. New opportunities exist in informing the wearer about his/her emotional state, notifications, messaging, or navigation guidance which can inspire many new and exciting research areas. As an output channel for bystanders, auricular postures also allow an impaired wearer incapable of using face or limb properly to express body language for their well-being. It is also interesting to explore using both ears or combining auricular postures with other social cues (e.g., facial expression) or communication mechanisms (e.g., speech).

Visibility. During our studies, the auricular postures were all clearly visible. However, the impacts of different viewing angles, existing body postures, or hair occlusions warrant more careful investigations. It is also important to examine if the postures performed by different ears (e.g. ears without an earlobe) can be interpreted coherently. We will address these issues in future works.

User studies. Our study only considered auricular postures in isolation with respect to other forms of body languages. Future research will study the role and effectiveness of auricular postures when used together with facial expression or other types of body posture. It would also be interesting to study the acceptability of the auricular postures with a more diverse group of participants in terms of age and occupation. Our study was conducted with participants from China. As such, the result of the studies may not be applicable in a different cultural setting. Future research will conduct studies with participants from different cultural backgrounds.

CONCLUSION

We propose actuating the ear, specifically the auricle, as a means of expressive output, particularly for scenarios that involve impairment. Through an exploratory study to elicit auricular postures, we designed an initial set of unique dynamic and static postures. We then examined how these postures relate to emotional states and found that dynamic postures involving stretching the helix in different speeds conveyed different pleasant emotions, while static postures that involved bending the top or side of the helix towards the center of the ear were more associated with unpleasant emotional states. Finally, we created a proof-of-concept using an ear-worn device to demonstrate technical feasibility. The device is composed of several off-the-shelf electronic components, miniature motors, and custom-made robotic arms. We evaluated the prototype in a preliminary user study, looking at social acceptability and comfort. Our results that the device was comfortable to wear, and that social acceptance heavily relied on the nature of their relationships with others. As research into technologies for expressive output continues to increase, we believe our work can inspire new ideas and designs for using the ear in other areas in a meaningful manner.

REFERENCES

1. Anthony P Atkinson, Winand H Dittrich, Andrew J Gemmell and Andrew W Young. 2004. Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception*, 33 (6). 717-746. DOI=https://doi.org/10.1068/p5096
2. M. Z. Bjelica, B. Mrazovac, I. Papp and N. Teslic. 2011. Busy flag just got better: Application of lighting effects in mediating social interruptions. *In Proceedings of the 34th International Convention MIPRO*, 975-980.
3. A Boissy, A Aubert, L Désiré, L Greiveldinger, E Delval and I Veissier. 2011. Cognitive sciences to relate ear postures to emotions in sheep. *Animal Welfare*, 20 (1). 47.
4. Margaret M Bradley, Brucse N Cuthbert and Peter J Lang. 1991. Startle and emotion: Lateral acoustic probes and the bilateral blink. *Psychophysiology*, 28 (3). 285-295.DOI=https://doi.org/10.1111/j.1469-8986.1991.tb02196.x
5. Rafael A Calvo, Sidney D'Mello, Jonathan Gratch and Arvid Kappas. 2015. The Oxford handbook of affective computing.*Oxford Library of Psychology.* DOI= http=//dx.doi.org/10.1093/oxfordhb/9780199942237.001.0001
6. Daniel Cernea and Andreas Kerren. 2015. A survey of technologies on the rise for emotion-enhanced interaction.*Journal of Visual Languages & Computing*,31,PartA.70-86. DOI=https://doi.org/10.1016/j.jvlc.2015.10.001
7. Daniel Cernea, Christopher Weber, Achim Ebert and Andreas Kerren. 2013. Emotion scents: a method of representing user emotions on GUI widgets. *Visualization and Data Analysis* . DOI:https://doi.org/10.1117/12.2001261
8. Daniel Cernea, Christopher Weber, Achim Ebert and Andreas Kerren. 2015. Emotion-prints: interaction-driven emotion visualization on multi-touch interfaces. *In Proceedings of SPIE/IS&T Electronic Imaging,* SPIE, 93970A. DOI:https://doi.org/10.1117/12.2076473
9. Daniel Cernea, Christopher Weber, Andreas Kerren and Achim Ebert. 2014. Group Affective Tone Awareness and Regulation through Virtual Agents. *In Proceeding of IVA 2014 Workshop on Affective Agents, Boston, MA, USA, 27-29 August, 2014*, 9-16.
10. Charles Darwin. 1998. The expression of the emotions in man and animals. *Oxford University Press, USA.* DOI=http://dx.doi.org/10.1037/10001-000
11. Beatrice de Gelder and Nouchine Hadjikhani. 2006. Non-conscious recognition of emotional body language. *NeuroReport*, 17 (6). 583-586. DOI= http://dx.doi.org/10.1097/00001756-200604240-00006
12. Laura Devendorf, Joanne Lo, Noura Howell, Jung Lin Lee, Nan-Wei Gong, M. Emre Karagozler, Shiho Fukuhara, Ivan Poupyrev, Eric Paulos and Kimiko Ryokai. 2016. "I don't Want to Wear a Screen": Probing Perceptions of and Possibilities for Dynamic Displays on Clothing. *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ACM, Santa Clara, California, USA, 6028-6039. DOI=http://dx.doi.org/10.1145/2858036.2858192
13. Necomimi - Brainwave Cat Ears. https://store.necomimi.com/
14. Paul Ekman. 2006. Darwin and facial expression: A century of research in review. *Ishk.*
15. Barrett Ens, Tovi Grossman, Fraser Anderson, Justin Matejka and George Fitzmaurice. 2015. Candid Interaction: Revealing Hidden Mobile and Wearable Computing Activities. *In Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*, ACM, Charlotte, NC, USA, 467-476. DOI=http://dx.doi.org/10.1145/2807442.2807449
16. Kathryn Finlayson, Jessica Frances Lampe, Sara Hintze, Hanno Würbel and Luca Melotti. 2016. Facial Indicators of Positive Emotions in Rats. *PloS one*, 11 (11).e0166446. DOI:http://dx.doi.org/10.1371/journal.pone.0166446
17. Kyosuke Fukuda. 2001. Eye blinks: new indices for the detection of deception. *International Journal of Psychophysiology*, 40 (3). 239-245. DOI=http://dx.doi.org/10.1016/S0167-8760(00)00192-6
18. Mayank Goel, Leah Findlater and Jacob Wobbrock. 2012. WalkType: using accelerometer data to accomodate situational impairments in mobile touch screen text entry *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, Austin, Texas, USA, 2687-2696. DOI=http://dx.doi.org/10.1145/2207676.2208662
19. V. Goverdovsky, D. Looney, P. Kidmose and D. P. Mandic. 2016. In-Ear EEG From Viscoelastic Generic Earpieces: Robust and Unobtrusive 24/7 Monitoring. *IEEE Sensors Journal*, 16 (1). 271-277. DOI=http://dx.doi.org/10.1109/JSEN.2015.2471183
20. Saul Greenberg, Michael Boyle and Jason Laberge. 1999. PDAs and shared public displays: Making personal information public, and public information personal. *Personal Technologies*, 3 (1). 54-64. DOI=http://dx.doi.org/10.1007/bf01305320
21. M. Melissa Gross, Elizabeth A. Crane and Barbara L. Fredrickson. 2010. Methodology for Assessing Bodily Expression of Emotion. *Journal of Nonverbal Behavior*, 34 (4). 223-248. DOI=http://dx.doi.org/10.1007/s10919-010-0094-x
22. Chris Harrison, John Horstman, Gary Hsieh and Scott Hudson. 2012. Unlocking the expressivity of point

lights. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 1683-1692. DOI=http://dx.doi.org/10.1145/2207676.2208296

23. Chris Harrison, Gary Hsieh, Karl DD Willis, Jodi Forlizzi and Scott E Hudson. 2011. Kineticons: using iconographic motion in graphical user interface design. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 1999-2008. DOI=http://dx.doi.org/10.1145/1978942.1979232
24. Masashi Hasegawa, Nobuyo Ohtani and Mitsuaki Ohta. 2014. Dogs' body language relevant to learning achievement. *Animals*, 4 (1). 45-58. DOI=http://dx.doi.org/10.3390/ani4010045
25. Mariam Hassib, Max Pfeiffer, Stefan Schneegass, Michael Rohs and Florian Alt. 2017. Emotion Actuator: Embodied Emotional Feedback through Electroencephalography and Electrical Muscle Stimulation. *In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, Denver, Colorado, USA, 6133-6146. DOI=http://dx.doi.org/10.1145/3025453.3025953
26. Noura Howell, Laura Devendorf, Rundong Tian, Tomás Vega Galvez, Nan-Wei Gong, Ivan Poupyrev, Eric Paulos and Kimiko Ryokai. 2016. Biosignals as Social Cues: Ambiguity and Emotional Interpretation in Social Displays of Skin Conductance. *In Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, ACM, Brisbane, QLD, Australia, 865-870. DOI=http://dx.doi.org/10.1145/2901790.2901850
27. Viirj Kan, Katsuya Fujii, Judith Amores, Chang Long Zhu Jin, Pattie Maes and Hiroshi Ishii. 2015. Social Textiles: Social Affordances and Icebreaking Interactions Through Wearable Social Messaging. *In Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*, ACM, Stanford, California, USA, 619-624. DOI=http://dx.doi.org/10.1145/2677199.2688816
28. Rajesh K. Kana and Brittany G. Travers. 2012. Neural substrates of interpreting actions and emotions from body postures. *Social Cognitive and Affective Neuroscience*, 7 (4). 446-456. DOI=https://doi.org/10.1093/scan/nsr022
29. Shaun K Kane. 2009. Context-enhanced interaction techniques for more accessible mobile phones. *In Proceedings of ACM SIGACCESS Accessibility and Computing* (93). 39-43. DOI=https://doi.org/10.1145/1531930.1531936
30. Marije Kanis, Niall Winters, Stefan Agamanolis, Anna Gavin and Cian Cullinan. 2005. Toward wearable social networking with iBand. *In Proceedings of CHI '05 Extended Abstracts on Human Factors in Computing Systems*, ACM, Portland, OR, USA, 1521-1524. DOI=https://doi.org/10.1145/1056808.1056956
31. Hsin-Liu Kao, Deborah Ajilo, Oksana Anilionyte, Artem Dementyev, Inrak Choi, Sean Follmer and Chris Schmandt. 2017. Exploring Interactions and Perceptions of Kinetic Wearables. *In Proceedings of the 2017 Conference on Designing Interactive Systems*, ACM, Edinburgh, United Kingdom, 391-396. DOI=https://doi.org/10.1145/3064663.3064686
32. Hsin-Liu Kao, Manisha Mohan, Chris Schmandt, Joseph A. Paradiso and Katia Vega. 2016. ChromoSkin: Towards Interactive Cosmetics Using Thermochromic Pigments. *In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, ACM, Santa Clara, California, USA, 3703-3706. DOI=https://doi.org/10.1145/2851581.2890270
33. Takashi Kikuchi, Yuta Sugiura, Katsutoshi Masai, Maki Sugimoto and Bruce H. Thomas. 2017. EarTouch: turning the ear into an input surface. *In Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services*, ACM, Vienna, Austria, 1-6. DOI=http://dx.doi.org/10.1145/3098279.3098538
34. Andrea Kleinsmith, P Ravindra De Silva and Nadia Bianchi-Berthouze. 2006. Cross-cultural differences in recognizing affect from body posture. *Interacting with Computers*, 18 (6). 1371-1389. DOI=http://dx.doi.org/10.1016/j.intcom.2006.04.003
35. Kostiantyn Kucher, Daniel Cernea and Andreas Kerren. 2016. Visualizing excitement of individuals and groups. *In Proceedings of the 2016 EmoVis Conference on Emotion and Visualization*, Linkoping University, Sonoma, CA, 15-22. DOI=http://dx.doi.org/10.3384/ecp10303
36. Xin Li, Ihab Hijazi, Reinhard Koenig, Zhihan Lv, Chen Zhong and Gerhard Schmitt. 2016. Assessing essential qualities of urban space with emotional and visual data based on gis technique. *ISPRS International Journal of Geo-Information*, 5 (11). 218. DOI=http://dx.doi.org/10.3390/ijgi5110218
37. James Jenn-Jier Lien, Takeo Kanade, Jeffrey F Cohn and Ching-Chung Li. 2000. Detection, tracking, and classification of action units in facial expression. *Robotics and Autonomous Systems*, 31 (3). 131-146. DOI=http://dx.doi.org/10.1016/S0921-8890(99)00103-7
38. Kristen A Lindquist, Tor D Wager, Hedy Kober, Eliza Bliss-Moreau and Lisa Feldman Barrett. 2012. The brain basis of emotion: a meta-analytic review. *Behavioral and brain sciences*, 35 (3). 121-143. DOI=http://dx.doi.org/10.1017/S0140525X11000446
39. Roman Lissermann, Jochen Huber, Aristotelis Hadjakos, Suranga Nanayakkara and Max Mühlhä. 2014. EarPut: augmenting ear-worn devices for ear-based interaction. *In Proceedings of the 26th Australian Computer-Human Interaction Conference*

on Designing Futures: the Future of Design, ACM, Sydney, New South Wales, Australia, 300-307. DOI=http://dx.doi.org/10.1145/2686612.2686655

40. Y. Liu, O. Sourina and M. K. Nguyen. 2010. Real-Time EEG-Based Human Emotion Recognition and Visualization. *In Proceedings of International Conference on Cyberworlds*, 262-269. DOI=http://dx.doi.org/10.1109/CW.2010.37
41. David Matsumoto and Paul Ekman. 1989. American-Japanese cultural differences in intensity ratings of facial expressions of emotion. *Motivation and Emotion*, 13 (2). 143-157. DOI=http://dx.doi.org/10.1007/bf00992959
42. David Matsumoto, Hyi Sung Hwang, Lisa Skinner and Mark Frank. 2011. Evaluating truthfulness and detecting deception. *FBI L. Enforcement Bull.*, 80. 1.
43. Bengt Mattsson and Monica Mattsson. 2002. The concept of "psychosomatic" in general practice. Reflections on body language and a tentative model for understanding. *Scandinavian Journal of Primary Health Care*, 20 (3). 135-138. DOI=http://dx.doi.org/10.1080/028134302760234564
44. Matthew Mauriello, Michael Gubbels and Jon E. Froehlich. 2014. Social fabric fitness: the design and evaluation of wearable E-textile displays to support group running. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, Toronto, Ontario, Canada, 2833-2842. DOI=http://dx.doi.org/10.1145/2556288.2557299
45. Hanneke K. M. Meeren, Corné C. R. J. van Heijnsbergen and Beatrice de Gelder. 2005. Rapid perceptual integration of facial expression and emotional body language. *In Proceedings of the National Academy of Sciences of the United States of America*, 102 (45). 16518-16523. DOI=http://dx.doi.org/10.1073/pnas.0507650102
46. Albert Mehrabian. 1969. Significance of posture and position in the communication of attitude and status relationships. *Psychological Bulletin*, 71 (5). 359. DOI=http://dx.doi.org/10.1037/h0027349
47. Albert Mehrabian. 1971. *Silent Messages*, Belmont, CA: Wadsworth. ISBN 0-534-00910-7.
48. C. Metzger, M. Anderson and T. Starner. 2004. FreeDigiter: a contact-free device for gesture control. *In Proceedings of Eighth International Symposium on Wearable Computers*, 18-21. DOI=http://dx.doi.org/10.1109/ISWC.2004.23
49. Mary E. O'Donnell. 2009. Communicative language teaching in action: Putting principles to work by BRANDL, KLAUS. *The Modern Language Journal*, 93 (3). 440-441. DOI=http://dx.doi.org/10.1111/j.1540-4781.2009.00901_3.x
50. Simon Olberding, Kian Peen Yeo, Suranga Nanayakkara and Jurgen Steimle. 2013. AugmentedForearm: exploring the design space of a display-enhanced forearm. *In Proceedings of the 4th Augmented Human International Conference*, ACM, Stuttgart, Germany, 9-12. DOI=http://dx.doi.org/ 10.1145/2459236.2459239
51. Jennifer Pearson, Simon Robinson and Matt Jones. 2015. It's About Time: Smartwatches as Public Displays. *In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, ACM, Seoul, Republic of Korea, 1257-1266. DOI=http://dx.doi.org/ 10.1145/2702123.2702247
52. Barbara Pease and Allan Pease. 2008. The definitive book of body language: The hidden meaning behind people's gestures and expressions. *Bantam.*
53. Esben W Pedersen, Sriram Subramanian and Kasper Hornbæk. 2014. Is my phone alive?: a large-scale study of shape change in handheld devices using videos. *In Proceedings of the 32nd annual ACM conference on Human factors in computing systems*, ACM, 2579-2588. DOI=http://dx.doi.org/10.1145/2556288.2557018
54. Alastair Pennycook. 1985. Actions speak louder than words: Paralanguage, communication, and education. *Tesol Quarterly*, 19 (2). 259-282. DOI=http://dx.doi.org/10.2307/3586829
55. Helen S Proctor and Gemma Carder. 2014. Can ear postures reliably measure the positive emotional state of cows? *Applied Animal Behaviour Science*, 161. 20-27. DOI=http://dx.doi.org/10.1016/j.applanim.2014.09.015
56. JA Ressel. 1980. A circumplex model of affect. *J. Personality and Social Psychology*, 39. 1161-1178. DOI=http://dx.doi.org/10.1037/h0077714
57. Sanneke J. Schouwstra and J. Hoogstraten. 1995. Head Position and Spinal Position as Determinants of Perceived Emotional State. *Perceptual and Motor Skills*, 81 (2). 673-674. DOI=http://dx.doi.org/10.2466/pms.1995.81.2.673
58. Andrew Sears, Min Lin, Julie Jacko and Yan Xiao. 2003. When computers fade: Pervasive computing and situationally-induced impairments and disabilities. *In Human-Computer Interaction: Theory and Practice (Part II).* 1298-1302.
59. Andrew Sears, Mark Young and Jinjuan Feng. 2003. Physical disabilities and computing technologies: an analysis of impairments. *Human Computer Interaction Designing For Deverse Users And Domains* DOI=http://dx.doi.org/10.1201/9781420088885.ch5
60. Marcos Serrano, Barrett M. Ens and Pourang P. Irani. 2014. Exploring the use of hand-to-face input for interacting with head-worn displays. *In Proceedings of the 32nd annual ACM conference on Human factors in computing systems*, ACM, Toronto, Ontario, Canada,

3181-3190. DOI=http://dx.doi.org/10.1145/2556288.2556984

61. Jaime Snyder, Mark Matthews, Jacqueline Chien, Pamara F. Chang, Emily Sun, Saeed Abdullah and Geri Gay. 2015. MoodLight: Exploring Personal and Social Implications of Ambient Display of Biosensor Data. *In Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, ACM, Vancouver, BC, Canada, 143-153. DOI=http://dx.doi.org/10.1145/2675133.2675191
62. Kiley Sobel, Alexander Fiannaca, Jon Campbell, Harish Kulkarni, Ann Paradiso, Ed Cutrell and Meredith Ringel Morris. 2017. Exploring the Design Space of AAC Awareness Displays. *In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, Denver, Colorado, USA, 2890-2903. DOI=http://dx.doi.org/10.1145/3025453.3025610
63. Reiner Sprengelmeyer, Andrew W. Young, Ulrike Schroeder, Peter G. Grossenbacher, Jens Federlein, Thomas Buttner and Horst Przuntek. 1999. Knowing no fear. *In Proceedings of the Royal Society of London. Series B: Biological Sciences*, 266 (1437). 2451. DOI=http://dx.doi.org/10.1098/rspb.1999.0945
64. Dag Svanaes and Martin Solheim. 2016. Wag Your Tail and Flap Your Ears: The Kinesthetic User Experience of Extending Your Body. *In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, ACM, Santa Clara, California, USA, 3778-3779. DOI=http://dx.doi.org/10.1145/2851581.2890268
65. Yuanyuan Tai. 2014. The Application of Body Language in English Teaching. *Journal of Language Teaching & Research*, 5 (5). DOI=http://dx.doi.org/10.4304/jltr.5.5.1205-1209
66. Anja Thieme, Helene Steiner, David Sweeney and Richard Banks. 2016. Body covers as digital display: a new material for expressions of body & self. *In Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct*, ACM, Heidelberg, Germany, 927-932. DOI=http://dx.doi.org/10.1145/2968219.2979135
67. Minh Hong Tran, Yun Yang and Gitesh K Raikundalia. 2005. Supporting awareness in instant messaging: an empirical study and mechanism design. *In Proceedings of the 17th Australia conference on Computer-Human Interaction: Citizens Online: Considerations for Today and the Future*, Computer-Human Interaction Special Interest Group (CHISIG) of Australia, 1-10. DOI =http://dx.doi.org/10.1145/1108368.1108401
68. Harald G Wallbott. 1998. Bodily expression of emotion. *European journal of social psychology*, 28 (6). 879-896. DOI=http://dx.doi.org/10.1002/(SICI)1099-0992(1998110)28:6<879::AID-EJSP901>3.0.CO;2-W
69. Wouter Walmink, Alan Chatham and Florian Mueller. 2014. Interaction opportunities around helmet design. *In Proceedings of the extended abstracts of the 32nd annual ACM conference on Human factors in computing systems - CHI EA '14* , ACM, Toronto, Ontario, Canada, 367-370. DOI=http://dx.doi.org/10.1145/2559206.2574803
70. Manuela Züger, Christopher Corley, André N. Meyer, Boyang Li, Thomas Fritz, David Shepherd, Vinay Augustine, Patrick Francis, Nicholas Kraft and Will Snipes. 2017. Reducing Interruptions at Work: A Large-Scale Field Study of FlowLight. *In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ACM, Denver, Colorado, USA, 61-72. DOI=http://dx.doi.org/10.1145/3025453.3025662