Implicit Ambient Surface Information: From Personal to Interpersonal

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ABSTRACT
We have proposed a novel concept: "Implicit Ambient Surface Information" (IASI), which is based on the notion that information on the surface of an agent (e.g., bodies and machines) is implicitly processed and affects collaborations between agents. To utilize IASI, it is necessary to develop technologies and analysis methods that can recode and decode implicit signals that appear on the surface of the body without disrupting the intended actions of users. We sought to gain insight into IASI and to utilize it to establish intelligent information processing systems by measuring implicit body movements, physiological responses, and mental states and thereby accumulate scientific knowledge for theoretical advances. We have applied this concept to measuring physiological states and body movement of a single athlete, and here describe a few studies, and then propose future directions, with greater focus on the mental and interpersonal aspects of IASI.

Author Keywords
Ambient; Argumentation; Implicit; Interpersonal; Sport

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

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INTRODUCTION
Wisdom computing and the consequential harmonious collaborations between humans and machines can contribute meaningfully to many potential application fields, such as learning and teaching [1], enhancing working experience, and promoting sports and cultural activities. During such processes, dynamic, mutual interactions are embedded as implicit and embodied knowledge [2], which are hard to realize or understand from the first-person perspective of humans (or machines). Cognitive science has investigated some interactions between more than two persons (e.g., [3,4]). However, the workings of implicit processes of embodied knowledge are largely unknown, and technologies utilizing such embodied knowledge will be vital for development of wisdom computing and harmonious human−machine collaborations.

Based on research projects on implicit information, we have proposed a novel concept: "Implicit Ambient Surface Information" (IASI). This is based on the notion that information on the "surface of an agent (e.g., bodies and machines)" is implicitly processed and influences interactions. In order to utilize IASI, it is important to develop technologies that recode and decode implicit body movements and physiological responses without disrupting the intended actions of users. A recent advance in performance material capable of measuring biometric information will provide a good point of initiation.

In the project ("Intelligent Information Processing Systems based on IASI," we aim to gain understanding of information that exists on the surfaces of the human body and machines but are largely ignored. We intend to utilize this information to establish intelligent information processing systems for creative human−machine collaboration.

In particular, we have tested technologies that recode and decode implicit body movements and physiological responses in the actual field, and have accumulated scientific knowledge for theoretical advances. While we have discovered multiple important and/or interesting findings and there have been numerous outputs from our research at this point, we introduce the results of a selected set of such studies in the following sections.

IMPLICIT AMBIENT SURFACE INFORMATION IN ACTUAL SPORTS FIELDS

In order to test the developed technologies and proposed theories and to aim for higher quality activities of humans in collaborations with machines, we first targeted practical fields (e.g., sports). Among other fields, we focused on sports, because implicit, embodied knowledge has been claimed to be important in sports, but we think it has not been well examined. One potential use of such information is to provide feedback of implicit processes to athletes and/or to coaches, to facilitate physical and mental regulation, and metacognition of their bodies and minds.

The recent development of hydrophilic high body-compatibility sensors has enabled us to measure body activities and heart rate continuously and stably. We have used these in several procedures to separate mental states from body states and activities. In essence, this involves measuring physical activities by means of acceleration sensors, and heart rate by means of hydrophilic sensors, and then developing a specific model to predict heart rate from physical activities during practice sessions, which is then subtracted from the actual heart rate. This concept is simple, but is has been quite difficult to test and obtain a sufficient amount of data in the real sports field.

In order to resolve this lack of data and test fields, we formed and registered a baseball team specifically for testing the devices and the system. This allowed us to identify and select possible physiological signals in the actual field and to accumulate knowledge, technology, and know-how for physiological measurement on the actual sports field (Figure 1). We successfully extracted mental states, including tension, anxiety, etc. (Figure 2). However, the exact mapping of the objective data to the subjective mental state still needs to be achieved by obtaining more data in the actual field.

Moreover, we have developed a system for visualizing the balance between sympathetic and parasympathetic nervous states, in order to measure the mental state during active movements. We have also developed a system for translating muscle activity into sounds (i.e., sonification of surface electromyography) and providing intuitive feedback to a user to adjust pitching form [5] (Figure 3). As the auditory feedback is given in real time (as compared with visual feedback, which is given offline), we expected that sonification and online feedback would improve learning of

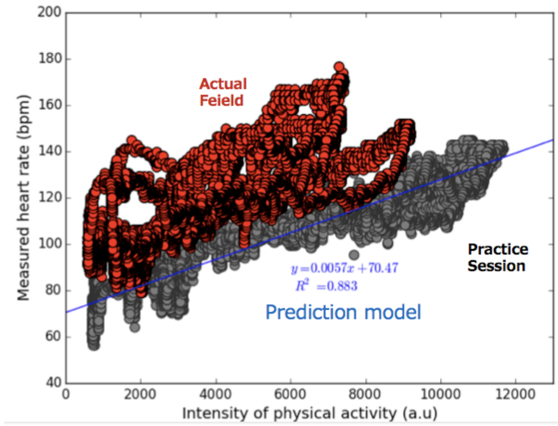

Figure 1. Model obtained by subtracting heart rates (HR) in practice sessions from those in the actual field in baseball play. Note that HRs are generally higher and more variable in the actual field. The prediction model is used for computing the HR difference online in the actual field. Physical activities were measured by the output of acceleration sensors.

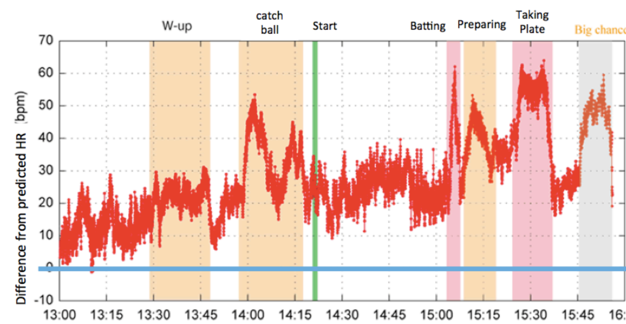

Figure 2. Difference in HR in the actual field during baseball play from single player. The blue line represents the predicted HR from the physical activities at a given time. The orange regions indicate the time when the player was under mild pressure and the pink regions indicate high pressure. Note that HR difference was high even when he was not on the ground and watching the game, which had a big chance at the end (one hit would lead to win the game after defeat seems certain).

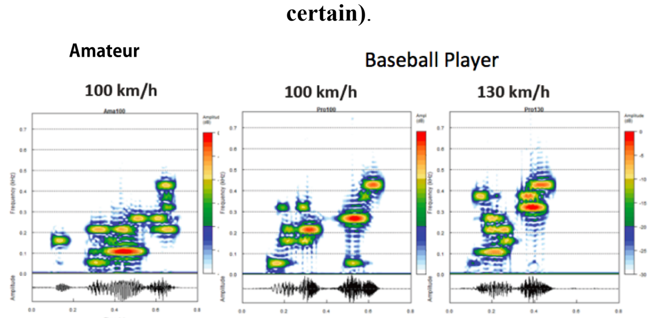

Figure 3. Example of sonification. Lower (higher) frequencies are assigned to lower (higher) parts of the body. Even when the ball speeds were the same (i.e., 100 km/h), the difference in coordination between lower and higher parts of the body and body movement (which were also translated into auditory feedback) were more articulated in professional baseball players. Note that the sounds are mapped more discrete in the baseball player.

pitching forms. These technologies and their fine-tuning in the actual sports fields could have various applications, including the analysis of whole-body synergy, the virtual reality system for implicit brain function analysis, and the Sports Brain Project initiative at NTT Communication Science Laboratories.

To date, our research has involved studies of single athletes, and has mostly focused on physical activities while we attempted to measure pressure, anxiety, tension, etc. However, we think that in order to achieve human-harmonized information systems, scientific knowledge and the technologies of measuring, decoding, and controlling human behaviors, in particular, implicit “interpersonal” information, are vital. Our project is based on the concept that and effective interpersonal communication depends strongly on implicit, non-symbolic information that emerges from dynamic interactions among agents. The other studies in our project clearly provide other scientific bases for future research and technological development. These objectives include delayed compensation by using implicit visuomotor responses, a screening procedure for autism spectrum disorders based on auditory and gaze processing, and objective measurements of immersiveness by using autonomic nervous and hormonal responses.

One example is the interpersonal interactions between an athlete and a coach. There are many potential pathways though which interpersonal information is conveyed: direct conversations, explicit and implicit feedback from the coach after observing the athlete’s movement, explicit and implicit bodily feedback from the athlete’s own actions, explicit and implicit feedback from observations of his/her own performance, social encouragement and discouragement, etc. Patterns appearing on the body surfaces would convey much information about the state of the athlete in the presence of the coach. In addition, it would be clear that some atmospheres could lead to either good or bad performances, often consequential and sometimes independent of the consequence of interactions among agents (for example, flow experience). This can be felt by those involved in the interaction; however, it is difficult to describe what these actually are, and even more difficult to implement processes that mediate such contexts. This is mainly because the agents do not notice these aspects, because they are focused on their activities.

Here, our technologies and the analysis method for implicit surface information would help to examine these aspects. That is, by examining the implicit surface information and their interactions among more than two athletes, coaches, and spectators, we might be able to detect, decode, and even utilize implicit surface ambient information.

IMPLICIT REALTIME MODULATION OF EMOTION BY OWN VOICE

Another implicit process that appears on the surface of our bodies is emotion. Emotion is difficult to control, because unconscious processes underlie both understanding and expression of emotions. In order to examine the effect of IASI on emotion, we have developed software that changes the emotional tone of voices online without noticeable delay (Da Amazing Voice Inflection Device: DAVID, Figure 4, [6]).

To test the effect of voice tone on the subjective evaluation of one’s own emotion, we let participants read a story alone and aloud and let them listen to their own voice (altered into happy, sad, or afraid). We found that people did not detect the manipulation of their own voices, but that their emotional state was changed toward the expected emotion [6,7]. In the field of psychology, the relationship between the expression and subjective feeling of emotions has been debated for a long time. The present study is the first to provide evidence of direct auditory feedback effects on emotional experience.

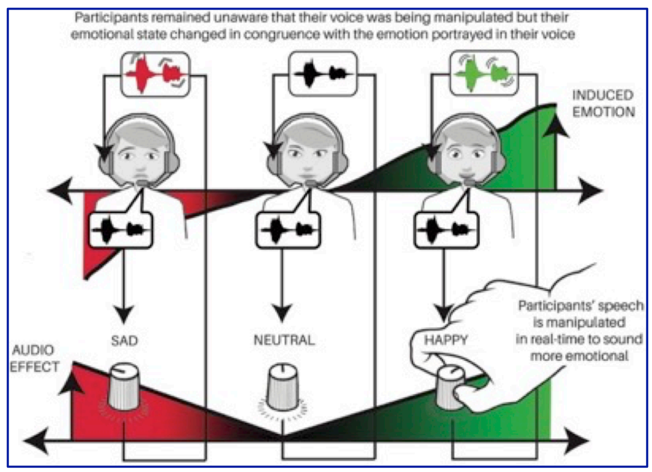

Figure 4. Implicit modulation of emotion can be achieved by using DAVID (Da Amazing Voice Inflection Device), a digital audio platform to modify the emotional tone of people’s voices while they are talking, and to make them sound more happy, sad, or fearful. Participants remained unaware that their voices were being manipulated.

We believe that DAVID may be used for both basic and applied research in many new fields. To date, emotional manipulation has not been done only on recorded but not on running speech (i.e., online). For example, DAVID could be used for mood disorders by inducing a positive emotional change or by redescribing traumatic events in a different tone of voice. It might also be possible to alter the emotional atmosphere of conversations in online meetings and sports games (e.g., in American football). DAVID can also be used for advanced modulation of mental states and can be combined with the wearable systems we proposed in the previous section for effective self-coaching, by modulating the emotion of the user.

Since the basic theoretical concept is based on the James–Lange theory of emotion [8] (i.e., emotion initially comes from bodily responses and interpretation of such responses by the brain), which holds that emotion arises from the interpretation of bodily signals, such surface information could also be used interpersonally. For example, changes in emotional and affective atmosphere might be induced by implementing the voice filters between two or more persons during casual conversations, business meetings, and teaching in a classroom. Such changes in atmosphere are considered as manifestations of IASI, because individuals are not aware that such information is being presented, and the effect is only noted interpersonally.

INDUCING AND DETECTING "FLOW" AND ITS NEURAL CORRELATES

As in the implicit modulation of emotion, subjective experience may be modulated and induced externally, and therefore may be shared by multiple persons. People play sports not only for achieving better performances, but also for experiencing special feelings. "Flow" is defined as a peculiar mental state and/or experience when a person plays sports, music, games, etc. with high-level performance. It is often characterized as a highly coordinated sensory-motor performance, extreme concentration, alteration of space and time, euphoria, etc. It has been suggested to be related to activation of the reward system, improved performance, and better team playing [9]. However, it has been difficult to replicate and/or simulate a state of flow. Our team has successfully found an experimental setup that induces a flow state by using computer games and has begun to measure behavioral, physiological, and neural correlates of flow. By starting from the experimental setup, we found that auditory evoked potentials (i.e., brain responses for task-irrelevant sounds) could be an index of flow state. This simple index could be used to detect a flow state in the actual field, including during sports, playing music, or in conversations, etc.

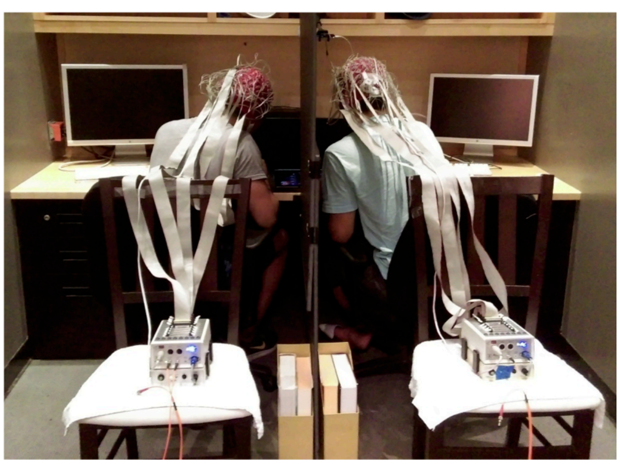

Figure 5. Measuring interpersonal flow by hyper-scanning (EEG) electroencephalogram.

A more recent study has also shown that we could produce a situation we termed "interpersonal flow," where flow experience appears to be shared by two persons, by letting two persons play a music game together, and confirmed this by both subjective ratings and performance scores. Furthermore, although preliminarily, we have measured two brains simultaneously (i.e., hyper-scanning) by using EEG, and found that auditory evoked potentials are reduced during the subjective experience of flow (Figure 5). This observation is yet another expression of IASI.

CONCLUSION

The present project aims at decoding and utilizing IASI, in order to both gain scientific understanding and to expand the appropriate use of this concept.

To date, we have shown that IASI can be measured and possibly used in individual athletes. While this is a significant advance in and expansion of the concept of such information and its range of application, we would like to advance and expand it even further. In particular, we propose to apply IASI analysis methods that we have established to decode and control "interpersonal IASI"

Most collaborative (or collective) behaviors occur during dynamic, reciprocal interactions [1]. This is particularly true when such activities involve many pieces of implicit knowledge [2]. Recent advancements in neuroscience and cognitive science have examined the multifaceted and dynamic processes in explicit and implicit interpersonal interactions [3, 4, 10-16].

To detect and decode interpersonal IASI, the reading and analyzing of information on the body surfaces would be valuable and increase knowledge and technological advances in implicit interpersonal information. We expect that scientific and technological advances in IASI will open a new field of harmonious collaboration between humans and machines and lead to wisdom computing.

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