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# Activating Environments and Minds with Displays

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**ABSTRACT**

*Displays are used not only for presenting visual information to people, but also as a means of transmitting data to information devices and for influencing people's behavior and minds. This paper provides an overview of display technologies that affect people and their surrounding environment.*

## 1 INTRODUCTION

Smartphones and smartwatches have become increasingly convenient, and people use mobile devices in all aspects of their daily lives. This integration of mobile devices into our daily lives has changed our behavior patterns. For example, we often see people moving in groups around the city or in parks, attracted by GPS games such as Pokémon GO [1]. People also often rush to photo-worthy restaurants to post photos on photo-sharing services such as Instagram [2]. Thus, mobile technology and its content have the ability to influence and induce day-to-day behavior.

Attempts have been made to use such information technology to enhance human physical and cognitive abilities. This is not limited to technologies that directly assist physical movement, such as power suits, for example, a camera is also a memory-enhancing medium. It stores episodes throughout a person's life in an external storage device, thereby expanding a person's cognitive abilities by assisting in memory retention and recall. The concept of information technology for intelligence amplification was proposed in the middle of the 20th century and is still being actively studied [3].

Interventions in the more subjective aspects of human emotion have also been widely studied. In this paper, the term of “emotion” includes feelings. Emotions are involuntary, so it is difficult to control them by oneself, but people are often asked to do so in various situations in daily life. Therefore, interventions have a wide range of applications, such as anxiety-reducing feedback methods for stressful speaking situations [5], emotional elicitation to support creativity in brainstorming [4], and supportting the expression of smiles during photography [6].

This paper introduces display technologies that activate the physical environment and minds of people. The concept of each display is as follows:

- **Activating the physical environment**: we realized "information projection technology", which gives functionality to devices in a space by transmitting data with pixels of light from a projector.
- **Promoting face to face communication**: we designed displays to promote communication during group work based on research in social cognitive science.
- **Evoking emotion**: we implemented displays by combining Virtual Reality (VR) technologies with research on the psychology of feeling and emotion.
- **Reinforcing memory retention**: we used VR and Augmented Reality (AR) displays to extend language memory retention for language learning.

## 2 ACTIVATING THE PHYSICAL ENVIRONMENT

The concept of Display-Based Computing (DBC) [7] has been proposed for environments where images and machines interact, in which the display itself, which has traditionally been a device for presenting visual information to humans, is used as a means of presenting information to machines. In the research of Display-Based Computing, the markers presented to the machine are projected as images. That is, the projected image is divided into two areas: one for humans and one for machines. In this situation the visual appearance of the image is degraded, and initialization and calibration for the machine is necessary.

In response to this, we have proposed the concept of Pixel-level Visible Light Communication (PVLC: Pixel-level Visible Light Communication) [8], which embeds bit information in every pixel of the image through high-speed blinking. Because data is represented by high-speed blinking, data can be sent to the terminal while the human eye only sees the image. A feature of this technology is that it can embed information where necessary without interfering with the video content being viewed by others. Since the data is embedded in the pixels themselves, it can be read instantly by holding up an information terminal with an optical receiver.

This technology projects a parallel communication channel with the number of pixels of the projector ( 1 024×768) onto the real world. For example, when a wearable tactile presentation device with an optical receiver is held up to the display , tactile feedback can be given to the user the moment the pixels are detected [9]. In another example, by projecting an image onto a group of robots with this projector, the robots could be controlled through the image without calibration (Fig. 1)

[10]. Another application of such a fast-controllable DLP projector we have developed is a spatially divided stroboscope [11]. General stroboscope is an instrument that produces brief repetitive spatially uniform flashes of light. When the frequency at which the light flashes is adjusted to the frequency of a moving object, the object appears to be stationary or slow-moving. The stroboscope we developed is implemented on a DLP projector, so the stroboscope effect can be controlled on a pixel-by-pixel independently. Fig. 2 shows an example of the spatially divided stroboscopic effect on a periodically moving string.

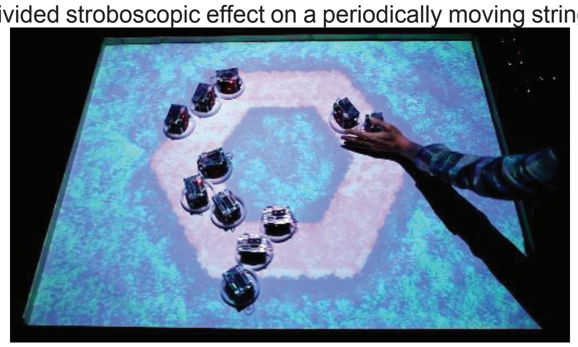

**Fig. 1 Phygital Field: an integrated field with a swarm of physical robots and digital images.**

**Fig. 2 Wobble Strings: spatially divided stroboscopic effect for augmenting wobbly motion of string instruments.**

## 3 PROMOTING FACE TO FACE COMMUNICATION

In this section, I present an attempt to use display technology to facilitate face-to-face communication between people. We have been offering a group work lecture called "Groupwork of Future - Discussions of the Future Made by Technology". and while practicing group work in this lecture, we noticed that PC displays and group work tools inhibit people's face-to-face communication. To mitigate this we implemented display technology to facilitate communication during group work.

We divided the factors that inhibit communication in co-located group work into two categories, "people" and "information technology" issues, and set to resolve each. The former is a psychological problem called "Evaluation Apprehension," which causes people to be concerned about the negative evaluation of others and reduces their comments due to anxiety [12]. The latter is a problem of using information technology, and it has been shown that conversations decrease when collaborative work is performed using a PC.

To address the first problem, we applied the "like" button on Facebook, an online tool for giving simple compliments, to co-located group work (Fig. 3) [13]. The system has built-in sound effects to express various kinds of positive feedback voices, and by simply pressing the button, members can praise others with large reactions. We tested it in a group work lecture, and found that it was pressed 577 times in 70 minutes, and that it has the potential to contribute to creating a positive atmosphere.


**Fig. 3 Naruhodo Button: Positive-feedback Button for Brainstorming with Interjection Sound Effects**

To address the second problem, we constructed a screen and data sharing system through tablet terminals placed on the back of the PC. A selected window inside PC is duplicated on the tablet terminal to show the users work status (Fig. 4). By touching the tablet terminal of other members, users can share the data with each other [14]. When using this system we observed it tended to improve discussion activity

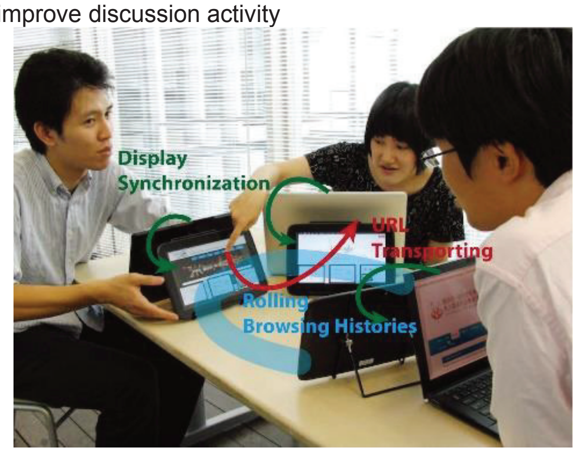


**Fig. 4 Round-Table Browsing : a system for supporting face-to-face collaborative web search**

## 4 EVOKING EMOTION

In entertainment and communication, it is important to elicit emotions at the right time. Based on our knowledge of the psychology and physiology of emotions, we have developed a method of eliciting emotions through external stimuli. Here, we mainly used tactile displays.

Emotions are felt by integrating signals from the sensory cortex and the limbic system based on the interoceptive senses, which are sensations originating from organs, autonomic nerves and hormonal responses of the body. We conceived of a technique to promote emotion in response to each of these three sources.

First, we considered applying stimuli that directly affect the autonomic nervous system, such as acupuncture and moxibustion, to entertainment, as they alter the interoceptive sensation itself. Specifically, we found that that listening to music while presenting a thermal stimulus to the neck changed the listener's impression of the music.

Second, external stimuli were superimposed on the signals to the sensory cortex as they were integrated. For this purpose, we implemented a device that presents vibrating stimuli to the earlobe in synchronization with sound (Fig. 5) [15]. By using this device, we showed that sweating amount (a physiological response to arousal) was increased, as were the experiences of pleasant and unpleasant emotions, excitement and tension.

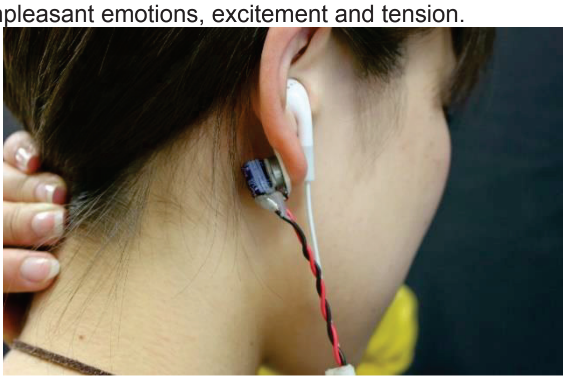

**Fig. 5 Emotional Vibration: Enhancing emotion using a combination of sound and tactile sensation to the earlobes**


**Fig. 6 Laughin' Cam: active camera system to induce natural smiles in photography**

Third, we examined a technique that uses empathy to elicit emotions. Specifically, we used emotional contagion, in which laughter induced laughter. For example, we designed a system in which puppets were placed in the vicinity of a comedy movie, and humans laughed in synchronization with the viewer's laughter [16]. We also created a system in which the camera bursts into laughter to induce a natural smile when taking a picture (Fig. 6) [6].

## 5 REINFORCING MEMORY RETENTION

In this section I present research on extending human memory retention with display technologies, an effort to use AR, and VR technologies to pioneer new vocabulary learning that prolongs the memorization of language.

Recent research on the neurophysiology and psychology of memory has revealed that 'emotion' and 'exercise' can prolong the episodic memory of learned scenes [6] [18] . For example, we may not be able to forget the experience of an emotionally-charged scene, such as a horror movie, even if we want to. In addition, exercise has the ability to create the optimal brain and body conditions for learning, such as by promoting neurogenesis, and by increasing brain-derived neurotrophic factor and noradrenaline levels. As a result, more and more high schools are incorporating physical education before academic classes.

We will integrate these effects of emotion and movement with VR/AR technology to create an effective vocabulary learning method for long-term memory. We will provide learners with an option to learn by "experience" accompanied by emotion and movement, rather than by mechanical repetition of English and Japanese from texts, in order to obtain long-term memory. In this way, we aimed to harmonize with social situations where studying abroad is difficult and there is little time to spend on vocabulary learning.

Regarding emotions, we implemented a method—"EmoTan"— to incorporate emotional stimulation into English vocabulary learning in flashcard applications on mobile devices (Fig. 7) [19]. To realize this, this application employs narration. Specifically, a story of several seconds in length is narrated to the learner, who can thereby perceive the contextual meanings of the words. To make it easier to induce emotional arousal with the story, we increased the sense of immersion using binaural recording. With this method, the learner can memorize the words using his/her emotionally rich episodic memory rather than semantic memory. For example, for the term "aerate", which means "to introduce air into something", a narration is recorded while blowing into a dummy head microphone. We compared the effects of binaural emotive narration with traditional textual flashcards on L2 word retention (immediate and delayed) in laboratory experiments with native Japanese-speaking English learners. Our results suggest that the learners were able to retain approximately 60% more L2 words long-term with the proposed approach compared to traditional flashcards.

For exercise, we developed a smartphone application, VocaBura, which combines audio learning with location-relevant L1-L2 word pairs to allow users to discover new vocabulary items while walking past buildings, shops and other locations (Fig. 8) [19]. Our tests indicated that Japanese beginner-level English learners were able to retain more vocabulary items with the proposed method compared to traditional audio-based study, despite being less aware of L2 vocabulary acquisition having occurred.


**Fig. 7 EmoTan: Enhanced Flashcards for Second Language Vocabulary Learning with Emotional Binaural Narration**

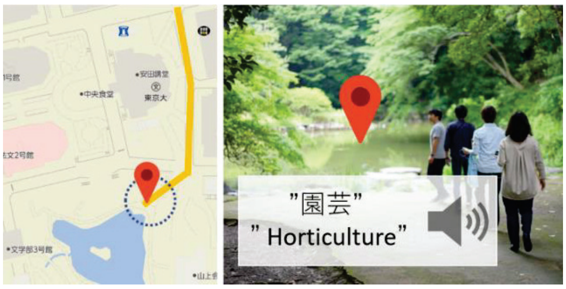


**Fig. 8 VocaBura: A Method for Supporting Second Language Vocabulary Learning While Walking**

## 6 CONCLUSIONS

In this paper, I introduced four aspects of the application of display technology. We expect that display technology and these application areas will evolve while integrating with each other.

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