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KAN.KA: Evaluating Across-Body Vibrotactile Patterns for the Design of Affective Furniture

Keio University
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Abstract of Master's Thesis of Academic Year 2019

KAN.KA: Evaluating Across-Body Vibrotactile Patterns for the Design of Affective Furniture

Category: Design

Summary

Emotion regulation plays an essential role in humans' life that enables people to function during cognitive tasks fully. Despite having an innate ability to regulate emotion, in real-life scenarios where a quick response is required, emotions often take over our mind, thus impair cognitive performance. KAN.KA aims to assist emotion regulation when people are engaging in a cognitive task.

KAN.KA is a concept of Affective Haptic Furniture that leverages directional vibration patterns across the body to induce positive emotions. We implemented the patterns onto a chair-like cushion and designed 25 vibration patterns that move around the upper and lower back, bottom and leg area of a person. We assessed the patterns in terms of the appropriateness to convey five different combinations of valence and arousal value, which lead to emotions such as happy, sad, calm, fear, and neutral. Based on the findings, we designed a scenario: reading a book, to assess the ability of the moving vibration pattern to regulate emotions while people are performing a task.

In addition, we also had the opportunity to test KAN.KA furniture with a community of older adults. The received feedback shows promising results of using the system to regulate emotions among the elderly people group.

Keywords:

Emotion Regulation, Affective Technology, Haptic Design, Across-Body Vibration Pattern, Smart Furniture

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Chapter 1

Introduction

1.1. Emotions in Daily lives

Figure 1.1 Emotional Distraction in Work (Photo by Tim Gouw on Unsplash)

It was in the middle of the work, where he just argued with his colleague. It was so frustrating, yet he had to suppress his emotion, not to cause commotion in the workplace. The event utterly ruined his mood yet he had to continue his work as per usual. He tried his best to do it, but just a few seconds he remembered the incident, it boiled him up again. The more he entertained the thought, the louder the tapping sound on his keyboard. His heart rate increased alongside with his breathing speed. His nostrils flared up. Tensed muscles around his neck. As the heat traveled from his chest to his throat, he made a loud grunt. By this time, if he could, he would probably have thrown a punch through the monitor screen right before him.

This experience was just one example of how emotions could sometimes be out of control and might affect our daily life activities. The impact of this overwhelming emotion varies from as simple as delayed work to a more severe case, for example, fear, anger or anxiety that kicks in while we are driving a car could lead us to an accident. Furthermore, this connection is not only true for negative emotions but as well as for positive emotions. For instance, an extreme excitement in the night while playing a game may inhibit us from taking a sleep at the right time.

Therefore, regardless of whether they are pleasant or unpleasant emotions, if we continue to neglect their effect on our lives, they could demerit us.

1.2. Emotion Regulation and its Challenges

As human beings, we are born with an innate ability to think on how to tackle the unwanted emotion, and as we mature, we also learn different strategies to apply in different situations. For instance, before a presentation, we try to take a deep breath to reduce nervousness. Another example, when we feel heartbroken or sad, we try to cheer ourselves up by eating a bucket of ice-cream. In his paper, James describes all these efforts to influence which emotions we have, when we have them, and how we experience them as emotion regulation (GROSS 2002). Emotion regulation is essential and helps people to function in their daily lives fully.

However, there are always cases where we are not able to control our feelings accurately, or our body fails to regulate emotions. The causes could be due to some disorders (e.g., dementia, temper tantrums, post-traumatic disorder, and so on.) or complex situations which prevent us from having enough time to think on the countermeasure — this type usually happens when we are dealing with a fast-paced situation, like driving a car. People who have never assessed their emotions would also have some difficulties in regulating their emotions.

This inability to regulate emotion led to a substantial body of research in human-computer interaction, looking at how to create new technological approaches that could assist us in regulating emotions and improve our well-being.

1.3. Current Focus on Emotion Regulation

Thus far, a lot of the technological offerings had been deployed to assist people in preventing or coping with unpleasant emotions. Maya Tamir, however, argued that what people need, might not be merely pleasant emotions, and introduced a concept of useful emotions. Useful emotions are all emotions, regardless of whether they are pleasant or unpleasant, that can be perceived positive if presented in the right context (Tamir 2009). For example, people who are risk-taker tend to gamble a lot. Scientists regard this situation as the effect of lacking a sense of fear. Hence, inducing a particular fear into these type of people would help them to stop gambling.

Furthermore, Costa et al. also mentioned that many of the current technological approaches require user's attention and effort which may affect or distract the user from continuing their activities (Costa et al. 2016).

After looking at the above states, there are several questions or focuses that appeared:

- how can we provide the right useful emotion at the right time without neglecting the importance of negative emotions as well?
- what kind of system should be developed in order not to disturb users' activities?

This thesis explores these questions and proposes the use of haptic technology to address them.

1.4. Haptic Technology as an Intervention for Emotion Regulation

One of the most common technologies used in the research of emotion regulation is haptic, mainly vibration, as it has been found to have properties that are suitable for designing technological aids to emotion regulation (Miri et al. 2017). Those properties include the ability to mimic human heartbeat sensation which is useful to make people more conscious of their emotional state by having them feeling their heartbeat vibration (Costa et al. 2016). Other previous research has also shown that vibration could be used to elicit emotions (Obrist et al. 2015),(Yoo et al. 2015).

However, the implementation is limited to a specific body part (upper body (Arafsha et al. 2015),(Lemmens et al. 2009), chest/waist/back (Tsetserukou and Neviarouskaya 2010), forearm (Tsalamlal et al. 2013), etc.), and mostly concentrating on or around the hand area (Obrist et al. 2015),(Yoo et al. 2015). In contrast, across-body vibration has been proven to enrich the experience for entertainment (Israr et al. 2012), (Baijal et al. 2012); however, its usage in invoking emotion reactions for emotion regulation has yet to be explored. Furthermore, across-body haptic opens up a more extensive range of design applications in emotion regulation (meditation (Ståhl et al. 2016), car-driving (for 2199)). Hence, in this thesis, not only we want to use the existing findings about haptic technology for emotion regulation, but we also want to explore a new area such as across-body vibration.

1.5. Proposal

Leveraging on vibration properties, and the potential of across-body haptic to deliver a new emotion regulation method, we propose a concept of affective haptic furniture. By embedding the vibration patterns into a piece of furniture, we see an opportunity to create new smart furniture that allows people to regulate their emotions while continuing to do their activities.

While trying to develop the system, we also identified several research questions that need to be addressed, such as: How do people perceive across-body haptics concerning emotional state? What are the criteria to design the affective furniture? These questions motivated the work in this thesis.

To sum it up, this thesis provides the following contributions:

- Evaluating across-body vibration patterns effect towards the perceived emotional state

- Applying these patterns to create KAN.KA, the affective haptic furniture that provides people with more access to useful emotions in their daily lives

1.6. Thesis Structure

This thesis consists of 6 chapters. Chapter 1 presents the background that describes the need for this thesis. Following that is chapter 2, which describes the foundational theory of emotion regulation, relevant research, concepts, and applications. Chapter 3 discusses the concept and technical implementation. Chapter 4 presents a series of studies to evaluate the system developed in chapter 3. Chapter 5 showcases the process of designing KAN.KA furniture into an actual product based on the feedback received in the studies. Finally, chapter 6 provides a summary of this work and offers some conclusions.

Chapter 2
Literature Review

2.1. Emotion Regulation Strategies

According to the Gross' "Process Model of Emotion Regulation", every person would go through five different phases before an emotion is generated (GROSS 2002). Moreover, by understanding the five steps, emotion regulation strategy could be applied more effectively. In the following section, we describe the five emotion phases and their corresponding emotion regulation strategy with a sample of the scenario.

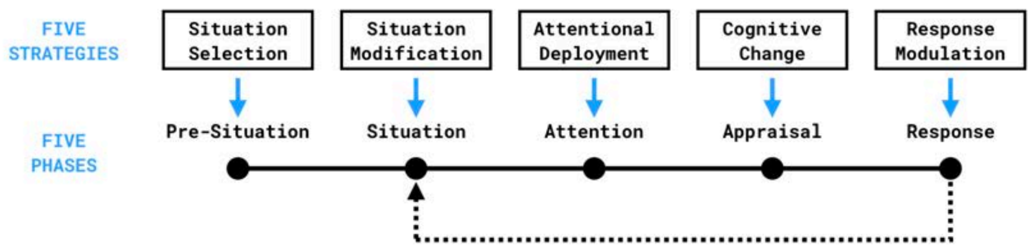


Figure 2.1 Process Model of Emotion Regulation (GROSS 2002)

- **Pre-Situation - Situation Selection**
  This stage is where users are not in any situation that could cause emotional change yet. An applicable approach in this stage is "Situation Selection," which refers to an act of selecting or avoiding the situation that will give rise to desirable or undesirable emotion. For example, if someone was walking down a street and suddenly he saw up ahead, there was someone that he

did not like. He could avoid the situation of meeting that person by taking another route.

- **Situation - Situation Modification**
  This stage is when someone is in the middle of a situation. For example, while he was watching a horror movie, he knew that the scene was about to enter the scary part. He could apply a strategy called "Situation Modification", an act of modifying the environment to change its emotional impact, such as turning all lights on to reduce the eerie atmosphere.

- **Attention - Attentional Deployment**
  Every situation has different things that users can put a focus on. When an emotion is about to emerge, users can apply "Attentional Deployment" strategy, in which they purposely direct their attention away from the emotion. For example, through meditation or breathing exercise, they could focus on the breathing pattern instead.

- **Appraisal - Cognitive Change**
  Aside from directing one's attention away from the emotion, users can also learn to assess the situation and change their thinking about it. This method is called the "Cognitive Change" strategy. For example, in a work scenario, when we got scolded by our senior. Instead of focusing on the terrible emotion of being scolded, we could try to understand the reason behind it and think of it as a learning experience instead.

- **Response - Response Modulation**
  This situation is when the emotion is already generated. We can apply a "Response Modulation" strategy. This method involves attempts to change our experiential, behavioral, and physiological response systems. An example of changing our behavioral response would be suppressing our facial expression, like in a solemn situation, we need to control our face not to show any smile or happy emotion. Another example would be letting users feel/hear their heartbeat to allow them to understand their emotion and learn to control them.

In this thesis, we will be using this process model of emotion regulation as the foundation to design an appropriate solution.

2.2. Non-Technological Solution for Emotion Regulation

As mentioned earlier, humans were born with an innate ability to regulate their emotions, such as through controlling their breathing pattern or making a decision that helps to counter the unwanted feelings. Furthermore, there are also non-technological solutions that have been explored to help to regulate emotions. In this section, we will briefly discuss some examples of the non-technological solution such as meditation and aromatherapy for comparison.

Mindfulness meditation, which describes as a practice that involves focusing own mind on own experiences (emotions, thoughts, and bodily sensations) in the present moment [1], has been observed to have a positive effect towards emotion regulation (Figure 2.2).

Figure 2.2 Mindfulness Meditation (Photo by Jyotirmoy Gupta on Unsplash)

In a study conducted by Zindel Segal, a group of participants, who have gone through a mindfulness training, viewed their emotions from a more detached perspective (Farb et al. 2010). It implies that they may be able to think more clearly to resolve their issues without emotional interference. While the results were positive, participants had to go through prior training for eight weeks. In a situation where time is not in favor or a scenario where we need to do different activity simultaneously, an 8-week-training might not be the appropriate solution for quick emotion regulation.

Another non-technological approach that could address the time issue would be aromatherapy (Figure 2.3). Winai et al. compared the effect of lavender and rosemary oil versus a base oil towards emotional states (Sayorwan et al. 2013), (Sayorwan et al. 2012). The study suggested that by inhaling the scented oil, participants felt more active, fresher, and relaxed than the base oil.

Figure 2.3 Aromatherapy (Photo by Drew L on Unsplash)

Despite odor's ability to evoke various emotions, emotional perception of odor is closely linked to emotional memory or experience (Kadohisa 2013). It means that people interpret odor depending on their experience. For instance, a smell that reminds a person of his hometown could induce a nostalgic and sad emotion. However, when the same smell is presented to a different person, a similar emotion may not be achieved. Similarly, in emotion regulation, a smell that regulates one's emotion might not give the same effect to a different person.

While non-technological solutions show possibility in emotion regulation, there are persisting constraints remained unsolved, such as time involved in meditation training or subjectivity in aromatherapy. Hence, in this thesis, we seek a technological approach to design an emotion regulation solution.

2.3. Technologies for Emotion Regulation

The goal of this thesis is to provide a technology intervention that helps people to regulate their emotions without disturbing them from their activities. In addition to the Gross' process model which will be our foundational method in designing our solution, we will also look at existing technological solutions, other than haptic, that focus on emotion regulation during a task. We will discuss them based on the strategies in Gross' process model, except for the situation selection strategy, as the focus is the generated emotion in/during a situation.

To begin with, Affective Remixer (Chung and Vercoe 2006) is one of the examples of how a situation modification can be implemented to regulate emotion. This technology collects physiological data of the user, which is the galvanic skin response data and rearranges the songs played based on users' immediate affective state. The song matches user's preference hence change the emotional impact of the situation.

The next one is attentional deployment strategy. One of the most common modalities to divert users' attention is a visual element. For instance, Maclean et al. conducted a study that aims to regulate stress while driving (MacLean et al. 2013). They invented MoodWings, which is a real-time biofeedback system that informs drivers of their stress level through wing actuation. When the stress level is increasing, the flapping of the wings also becomes faster (Figure 2.4).

While the driving performance and attention level to safety increased, there is a drawback in this system. The visual feedback became a stressor to the drivers. As the drivers could see their real-time stress level, they feel even more stressful.

Another study in the driving context took the approach of reappraising situation (cognitive change strategy) to reduce negative emotions after frustrating events such as being cut-off or long traffic lights. In contrast to visual feedback, this study uses voice interfaces that were designed to reframe the frustrating event (Harris and Nass 2011). For instance, if the driver got cut-off, the voice interface

Figure 2.4 MoodWings actuation system based on user's stress level (MacLean et al. 2013)

would interpret it as follow: "*The driver must not have seen you; otherwise, he would not have chosen to change lanes.*" The result of this study showed that the down-reframing helped participants had a better driving performance and a better emotional state outcome.

Finally, we will discuss an example of response modulation strategy, which is a strategy that focuses on increasing people's awareness of their own emotion hence enabling self-regulation. MoodLight is one example that leverages on the strategy (Snyder et al. 2015). It is an interactive ambient lighting system that responds to the user's current level or arousal. MoodLight uses a biosensing tool to collect the arousal data and present the data in different color hues (Figure 2.5).

Figure 2.5 MoodLight color changes based on user's arousal (Snyder et al. 2015)

In the study, users were able to understand their current emotion immediately and attempted to change the MoodLight color by changing their arousal state through some interactions. This result showed how increasing people's self-awareness of their emotion enables them to control it or achieve self-regulation.

2.4. Affective Haptics

Touch has long been known to play a prominent role in communicating or enhancing human's emotional experience. Affective haptic is an emerging interdisciplinary area of research in the human-computer interaction, which focuses on the design of a system that displays a human's emotional state utilizing the sense of touch. One of the most common haptic technologies used in this area is vibrotactile feedback. Vibrotactile feedback has many parameters that allow researchers to create a wide range of patterns to convey complex emotions.

The following section will discuss three categorizations of haptic implementation, focusing on vibrotactile feedback, for affective application: (1) Haptics for Emotion Communication, (2) Haptics for Emotion Enhancement, and (3) Haptics for Emotion Regulation.

2.4.1 Haptics for Emotion Communication

In our daily life, we often interpret or relate our surroundings to an emotional meaning, for example, when we see a red color poster, we find it more exciting as compared to a blue color poster. This psychology effect of colors and emotions is often used in the graphic design or advertising industry to communicate an emotional message. In the same way with colors, the study of haptics for emotion communication focuses on finding the common traits in haptic technology that could display basic emotions such as happy, sad, and so on. In this section, we will describe two common approaches to display emotions through haptic sensation.

- **Mimicking actions that express emotions**:
  Actions that involve touch has long been known to have a directional correlation with emotional expressions and perceptions. Through touch, we connect with others, experience certain feelings and build a sense of trust [2]. There are myriad of ways that touch is used as the basis of emotion communication, for instance, hug comforts a crying baby, hold hands expresses love to the partner or pat on the back to show empathy.

  By observing the impact of touch actions, many studies in human-computer interaction used the direct approach to copy those actions and translate

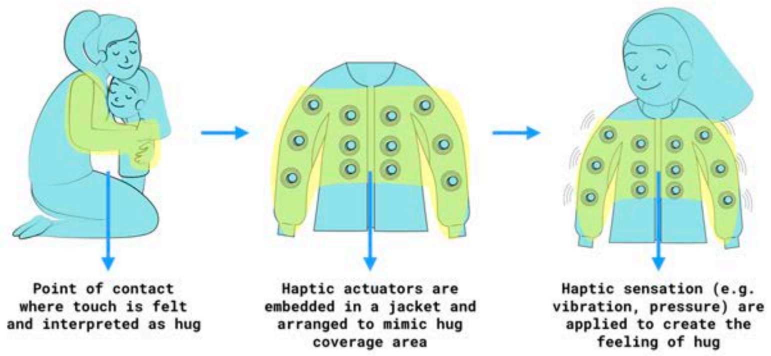


Figure 2.6 From Touch Action to Haptic Experience

them into haptic interaction. Figure 2.6 shows the process of mimicking touch action into a haptic experience.

In the past research, HugMe by Jongeun Cha used a set of vibrotactile actuators and created an effect that mimics touch sensation such as hugging or poking in online communication (Cha et al. 2008). Another example of this approach was Fukushima's chilly chair which used electrostatic force to raise back and forearm hair similar to the experience of goosebumps (Fukushima and Kajimoto 2012).

- **Mapping emotions into different stimuli patterns**:
  This approach is deriving meaning from a relationship between stimuli parameters to emotional perceptions. For instance, in the study of vibration pattern, by understanding how humans perceive vibration frequency or amplitude concerning emotional meaning, researchers could create a new analog experience to influence or induce emotions. Figure 2.7 portrays the process of understanding human perception.

  According to Luv Kohli et al., several parameters can be used to vary the characteristics of vibrotactile feedback to display different information (Kohli et al. 2006). Those parameters are frequency, amplitude, a temporal delay, and pulse patterns for a single vibrator. For several vibrators, the

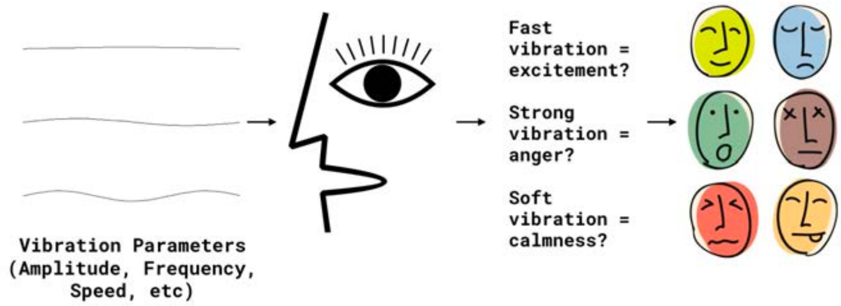


Figure 2.7 How Does Our Brain Make Meaning to Emotions

parameters expand to tactile movement patterns, body location, and interpolation method. Studies listed in Table 2.1 used a combination of these parameters in understanding emotion perception.

Table 2.1 Past research that leverages on vibrotactile parameters to display emotional information

Haptic Interface	Emotions	Stimulus Parameters	Results
Vibrotactile Jacket (Cha et al. 2008), (Arafsha et al. 2015)	Love, enjoyment, fear, sadness, anger, anxiety, happiness	Vibration intensity, duration and speed	Higher intensity/speed indicated surprise or happiness, continuous stimulation associated with love, high intensity down the spine for fear and anxiety
Vibrotactile Gloves (Krishna et al. 2010)	Happiness, sadness, surprise, anger, fear, disgust	Haptic expression icons	Happy is represented by a U shaped pattern, sad by an inverted U, surprise by a circle
Tactile Emojis (Zhang et al. 2018)	Happy, Sad, Surprised and anger	Breathing patterns	Short repeated vibration expresses sadness, high vibration frequency expresses anger
Vibration in Smartphone (Yoo et al. 2015)	Valence and Arousal	Amplitude, frequency, duration and envelope	Carrier frequency showed a positive correlation with valence, envelope frequency was negatively correlated to valence, increasing amplitude results in higher arousal and lower valence

Building off of these results, while additionally considering the tactile movement pattern, and location of vibration effect on the body location as our parameters, we determined vibrotactile stimuli would be an effective means for conveying a variety of emotions.

2.4.2 Haptics for Emotion Enhancement

The use of haptic in this category focuses on adding or enhancing the affective layer of another modality (e.g., images, music, video, and others), without mapping any haptic pattern to an emotional meaning. For instance, if we compare the experience of listening to just a piece of music and the experience of listening to a piece of music with video. Most people would choose music with a video to induce stronger emotional involvement or more immersive. These findings motivated a group of work that tried to see the effect of haptic in other modality towards the emotional state, mostly concentrating around entertainment experience.

In the early study, Nanayakkara created a haptic chair (Figure 2.8) that translated music into a full-body haptic sensation to enhance the musical experience for the hearing-impaired community (Nanayakkara et al. 2009). The results showed that participants were able to perceive music through the sound vibrations on different body parts. Another similar study called Skin Music (Hayes and Rajko 2017) projected sound as vibrations that moved along the seated user's arms and legs, up the back of their neck and even onto their hands. Based on the received feedback, this work showed that there was potential to enrich the affective aspect of the music experience.

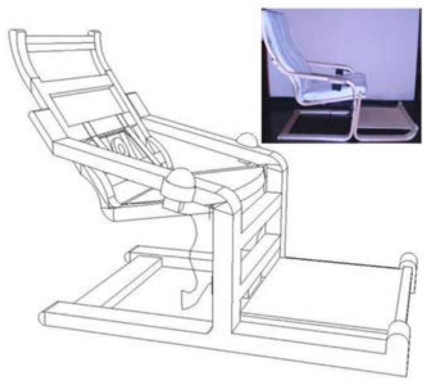


Figure 2.8 Haptic Chair to Enhance Musical Experience (Nanayakkara et al. 2009)

The use of haptic was further challenged by M. Giordano et al., who designed a whole-body haptic garment to enhance a multi-sensory art installation (Giordano et al. 2199) (Figure 2.9) . The garment consisted of 5 sets of 6 actuators that were applied to the left and right arm, torso, and left and right leg areas. The haptic effect was divided into two movement system: discrete and continuous effect. One of the examples of the continuous effect was a snake effect. This effect involved a wave of vibrations which traveled along the limbs, following a specified order. During the performance, the haptic feedback was matched to the activation of sound and light effects. Overall, the participants enjoyed the installation as they felt it was more engaging and provided elements of surprise.

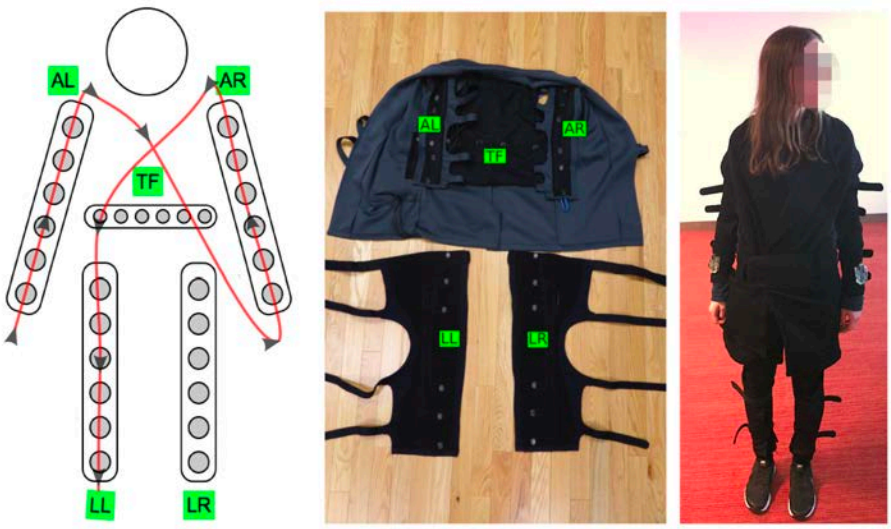


Figure 2.9 Whole-Body Haptic Garment in Multi-sensory Art Installationn (Giordano et al. 2199)

Surround Haptics by Israr et al. also took advantage of vibration motion across the body (Israr et al. 2012). They developed a system that used a low-resolution grid of vibrating actuators to generate smooth moving tactile strokes on the human skin. The system was embedded into a body-conforming chair and was part of a car gaming experience (Figure 2.10). It enabled the creation of different types of spatial tactile strokes to enhance game events such as collisions, tire traction, and acceleration. Although this did not directly correlate to emotion rendering, the motions from the vibrations were able to increase the user's level of excitement.

Figure 2.10 SurroundHaptic System (Israr et al. 2012)

The above works affirmed that haptic stimuli could increase the range of emotional expression and enrich the experience as a whole. We also identified two prominent treatments that appeared across the works: (1) haptic patterns were rendered to match the timing of the emotional content and (2) haptic patterns were rendered across the body parts. Across-body haptic was particularly interesting as it matched one study which mapped the bodily reactions caused by emotions (Nummenmaa et al. 2014). The study revealed that when people are experiencing a particular emotion, there is an increase or decrease in physical activity (e.g., skin temperature, muscle activation, breathing pattern, and others.) in a specific body area. The across-body haptic used in the above work proved to enrich an emotional experience. However, the design of across-body haptic patterns and its association to different types of emotions, in which this thesis tried to address, has yet to be explored.

2.4.3 Haptics for Emotion Regulation

The previous two categories of haptics application supported the idea that haptics can elicit emotion and enrich an emotional experience, which led haptics to be a popular choice for emotion regulation (Miri et al. 2017). Haptics for emotion regulation can be designed and deployed effectively by applying the Gross' Process Model of Emotion Regulation (GROSS 2002).

For instance, Jean Costa developed a haptic intervention that focuses on regulating emotion during the phase of attentional deployment (Costa et al. 2016). The watch-like device called EmotionCheck produces subtle vibrations that stimulate heartbeats. They hypothesized that a slow heart rate feedback (60 beats per minute) could influence users to feel less anxious during stressful situations.

In the experiment, users would go through a job interview exercise where they would be required to prepare a presentation. The slow heart rate vibrations would be played during the task. The results of the experiment showed that the intervention managed to keep the anxiety level of the participants at low levels. Overall, the research envisions a usage scenario whereby the device gets activated automatically when an external sensor detects that the user is anxious or stressed.

In a different study, Miri et al. suggested three broad ways in which haptics could augment emotion regulation strategies (Miri et al. 2017) (Figure 2.11).

- **Haptics as an aid to attention deployment strategy**
  Haptics can be used to disengage user's attention from the environment that caused undesirable emotion. As an example, upon detecting increased arousal, a gamified haptic task could ask users to count how many haptic patterns that are rendered.

- **Haptics to aid cognitive change by cueing particular reappraisals**
  A set of haptic patterns could be designed to represent different contextual cues (e.g., a pattern that reminds the user that unpleasant situation builds resilience). In this method, users would need to go through training to understand the meaning of each haptic pattern.

- **Haptics as an aid to response modulation** Haptic signals could mimic bodily responses of an emotional state (e.g., slow heart rate or breathing pattern). When haptic patterns are displayed in conjunction with an emotional state, they could intensify the effect. This method aligns with the theory of interoceptive awareness, which revealed that there is a connection between the degree of a person's awareness of their bodily signals and the intensity of the emotional experience (Pollatos et al. 2007).

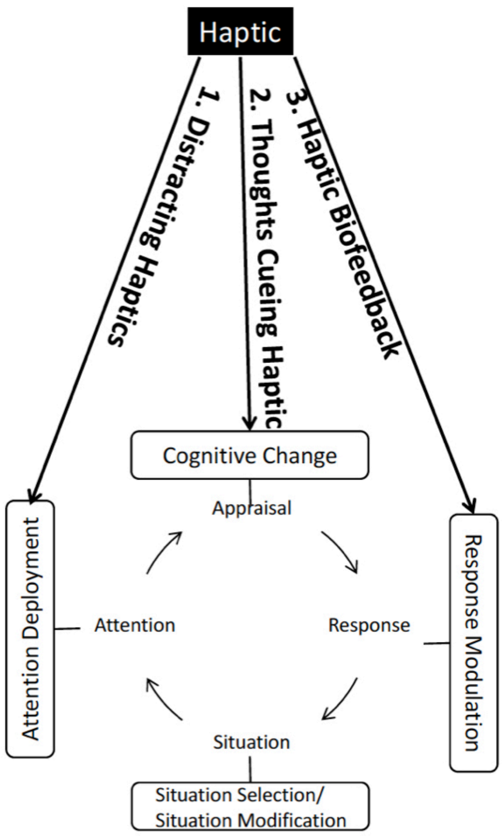


Figure 2.11 Haptic Augmentation for Emotion Regulation

The above work shared the importance of focusing on a particular phase of emotion experience to generate an effective haptic system. Similarly, this thesis will design a haptic solution for a specific emotion phased based upon Gross' model (GROSS 2002).

2.5. Summary

Overall, we found that a technology solution could only give a more effective result if it is introduced in the right phase of the emotional experience, as described by James Gross (GROSS 2002). Furthermore, we also discussed the existing solutions that were designed based on the same process model. However, most of the mentioned examples require user's consciousness to have an impact, while some of them may result in an opposite effect, such as in the driving context, the visual feedback becomes a stressor instead.

Therefore, it has become apparent that haptic, which are suggested to be more simple, personal, and subtle (Miri et al. 2017), could open a possibility to a less distracting emotion regulation solution during a task. Furthermore, haptic has also been proven to have a wide range of parameters and flexibility to elicit various emotions, which makes it a stronger candidate to solve the emotion regulation issue. Finally, by expanding the haptic touch field to more extensive body area could lead to an enhancement in emotion experience or added emotional involvement that results in an immersive experience. This finding encourages this thesis to use the full-body haptic implementation to design a non-distractive technology intervention.

Notes

1 https://www.verywellmind.com/mindfulness-meditation-88369

2 https://owlcation.com/stem/Our-Sense-of-Touch-and-Our-Emotions

Chapter 3
Concept Design

3.1. Designing for Emotion Regulation

When designing a technology intervention to help people regulating their emotion, according to Jean Costa et al., three fundamental questions first need to be addressed (Costa et al. 2016). In this section, we will describe our solution concept based on the three questions: (1) What to regulate? (2) When to regulate? (3) How to regulate?

3.1.1 What to Regulate

Emotional Distraction in Cognitive Tasks

On a day-to-day basis, we regularly involve ourselves in cognitive tasks, which requires focus and rational decision-making, for example, working in the office, writing a thesis, or driving a car. According to the early study of human's brain, the performance of these tasks depends on executive processes, such as working memory (Logie 1988), which is the ability to maintain and manipulate information relevant to the tasks over a short time. However, some challenges might interfere with this ability. One of the most potent distracters is emotional stimuli. Emotional stimuli could capture attention and reallocate processing resources and thus impair cognitive performance (Ellis and Ashbrook 1988), or often called as emotional distraction.

One particular study conducted a test that compared the effect of normal stimuli and emotional stimuli towards goal-oriented behavior and proved that emotional stimuli are more distracting than neutral stimuli (Dolcos and McCarthy 2006). Furthermore, a study on implications for distracted driving revealed that emotional valence and arousal could differentially influence driving behavior (Chan and Singhal 2015). This study also identified the harmful effects of negative emotional auditory content on driving performance.

In general, there are two types of emotional distraction: external and internal distraction. External emotional distraction comes from the environment around us or any external incident that might affect us emotionally. For instance, while you are driving a car, and someone recklessly cut into your lane. This incident may lead to a wave of anger that affects your driving performance.

On the other hand, internal emotional distraction comes from your imagination, thought, perceptions, or traumatic experience. For instance, fear of public speaking may lead your thoughts to enhance the negative emotion and interfere with your presentation (Figure 3.1), or after engaging in a long-hour activity, sometimes your mind might wander around your past memory or go into daydreaming mode. Therefore, regulating these emotions is essential so that we could perform well during the tasks.

Figure 3.1 Emotional Distraction while Giving a Presentation [1]

While external emotional distractions are more apparent and easier to get recognized, internal emotional distractions can remain hidden inside someone's mind and not regulated effectively. Therefore, this thesis decided to focus on designing a solution to regulate the internal emotional distractions that may interfere with the tasks. As the first step of the study, we will use the intervention for reading a book activity to see its effect against an internal emotional distraction.

3.1.2 When to Regulate

Referring to the Gross' model of emotion regulation discussed in the literature review, we will analyze the reading scenario across the five different emotion phases and first observe the strategies that could be applied without any technology intervention yet. After the observation, we will offer our proposed ideas on how haptic intervention could be integrated.

Reading Scenario - Internal Distraction

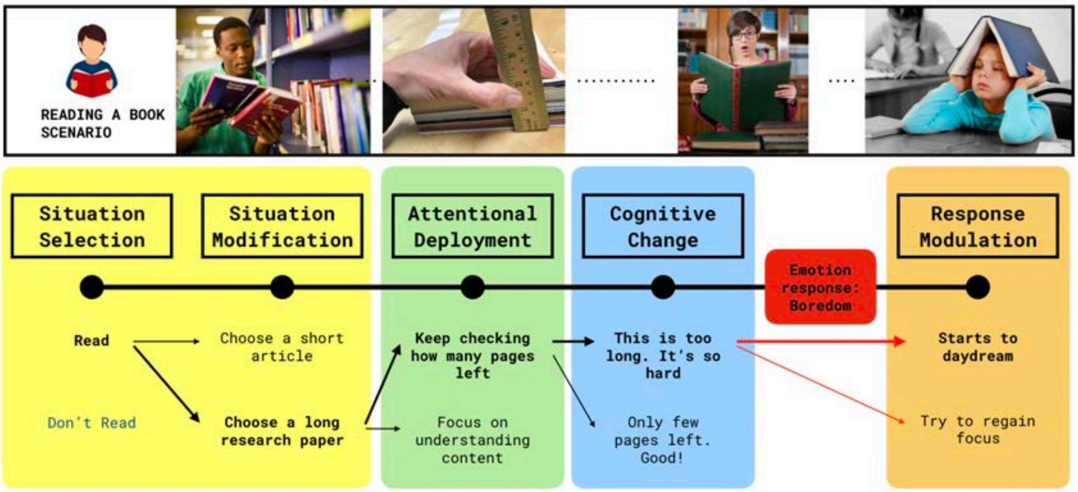


Figure 3.2 Emotion Generated in a Reading Scenario

Figure 3.11 illustrates how internal emotional distraction affects our reading experience. The possible haptic technology interventions at each stage would be as follow:

- **Situation Selection**
  As we are focusing on the situation where users already choose to read a book, we will not offer any solution at this stage.
- **Situation Modification**
  This strategy relies on changing the environment to modify the emotional impact; hence, it is possible to be used. For instance, a set of haptic patterns

that are embedded in the reading chair, and readers can choose to play their favorite pattern to improve the mood while reading the book.

- **Attentional Deployment**
  This strategy is also possible if we know readers' level of attention is dropping. We could prompt a haptic pattern that could give comfort to them hence bringing back their attention back to the reading activity.

- **Cognitive Change**
  This strategy requires users to analyze and interpret the meaning of the situation. As this activity might take an amount of user's focus, and a haptic intervention for this strategy requires prior training (Miri et al. 2017), this thesis will not be focusing on this strategy.

- **Response Modulation**
  This strategy works well for a long-hour activity in which emotion is already generated and continues to evolve throughout. An external sensor could be used to detect the user's emotional state, and in response to that, a suitable haptic pattern would be played automatically.

From the above discussion, "Situation Modification", "Attentional Deployment", and "Response Modulation" might be suitable to regulate emotions during the reading activity. However, both attentional deployment and response modulation requires a prior database of the user's emotional state and how the haptic patterns affect them emotionally. Hence, as the first step of the study, we will use the situation modification strategy to gather insights or data on how users perceive those haptic patterns during reading activity.

3.1.3 How to Regulate

Emotions in Movement

Previous studies demonstrate that there is a relationship between movement and emotion expression. William James (James 1894), stated that emotions are revealed through dynamic bodily expressions (Weerdesteijn et al. 2005) such as movement, body gesture, and facial expression.

This relationship was further explored by a study on Moving Design (Weerdesteijn et al. 2005), which integrated expressive movement into a product to elicit emotions. For example, as seen in Figure 3.3, joy was represented as an object with raised arms that would wobble back and forth when interacted with. Whereas, fear was imagined as an object that would curl up and making itself as small as possible. The results showed that the dynamic nature of an object was essential to express emotions.

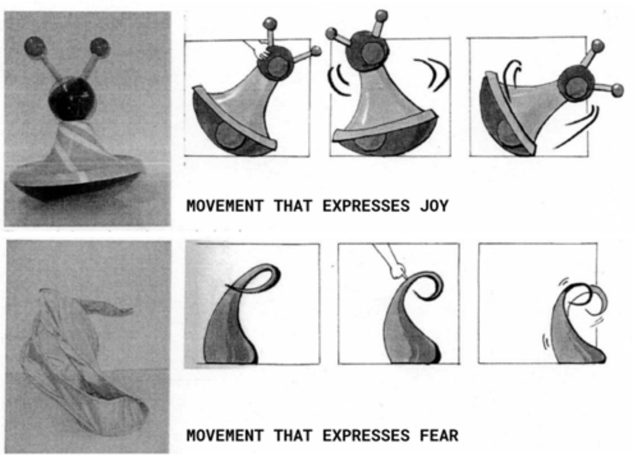


Figure 3.3 Movement in Objects that Expresses Emotions (Weerdesteijn et al. 2005)

In the context of haptic technology, a tactile stimulus moving across the skin has also been preferred to evoke a rich perceptual experience by many psychologists (Hall and Donaldson 1885).

This finding inspires the idea of designing various movements to represent different emotions. In the later chapter, we will discuss the design of a set of movement based on the input from a group of users.

Bodily Maps of Emotions

Depending on the cultural context, we often express our emotions with bodily related phrases such as: having butterflies in our stomach to communicate nervousness or feeling a shiver down the spine when we are feeling fear. This terminology shows that we associate emotions with bodily changes, and many studies have further established this relationship through in-depth psycho-physiological investigation.

A study which mapped the bodily reactions caused by emotions (Nummenmaa et al. 2014) revealed that when people are experiencing a particular emotion, there is an increase or decrease in physical activity in the specific body area. For instance, sensations in the upper limbs were most prominent in indicating anger or happiness, and sensations in the digestive system occurred with a feeling of disgust (Figure 3.4).

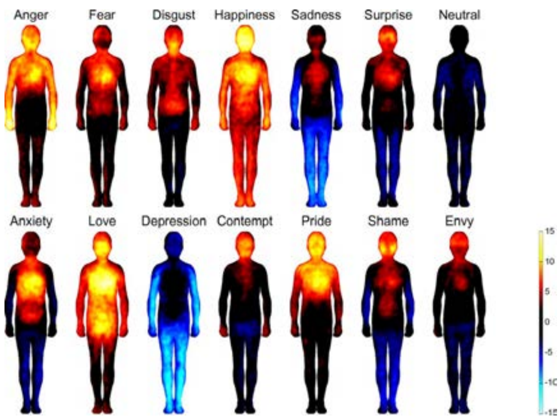


Figure 3.4 Bodily Map of Emotions (Nummenmaa et al. 2014)

Furthermore, other researchers found that emotion and the body is a two-way relationship, meaning that not only to emotion influence our bodily reactions but also certain external stimuli to the body can trigger an emotional experience. Therefore implies the possibility of applying external haptic sensation on different body areas to induce different emotions.

Inspired by the two ideas (Figure 3.5), we designed a piece of affective haptic furniture that renders moving vibration patterns across the body to influence people's perception of their emotional state. The next section will further explain the details of the furniture system.

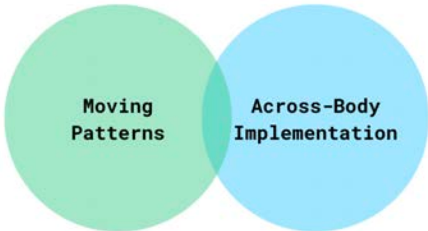


Figure 3.5 Main Elements in Affective Haptic Furniture

3.2. KAN.KA: Affective Haptic Furniture

KAN.KA (Figure 3.6) is our concept of affective haptic furniture that induces the right emotion needed by the seated users in their daily activities. Our system applies methods of mapping emotions with full-bodied haptics embedded in the furniture.

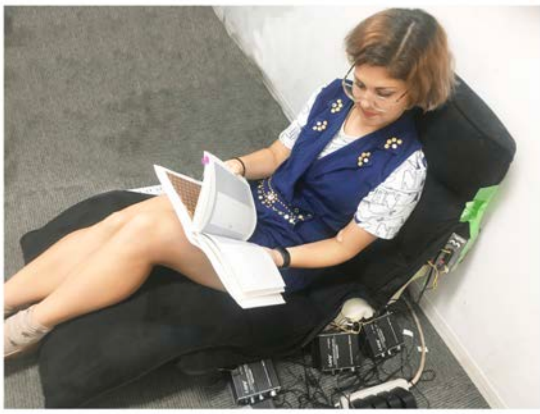


Figure 3.6 KAN.KA: Affective Haptic Furniture

We developed the furniture by using a body-conforming cushion that is adjustable to fit the user's sitting position. The actuators were movable and not fixed to the chair. These settings allow us to provide similar vibration pattern effects to users of different heights. Inspired by the heat map from the study in the bodily map of emotions (Figure 3.7), we chose to stimulate the following body regions: the upper back (chest), lower back (stomach), bottom (sitting area), and upper leg which have been observed to produce some reactions to different emotions. Furthermore, these areas could easily make direct contact with the seated user's body, thus maximizing the touch area for the moving vibrations.

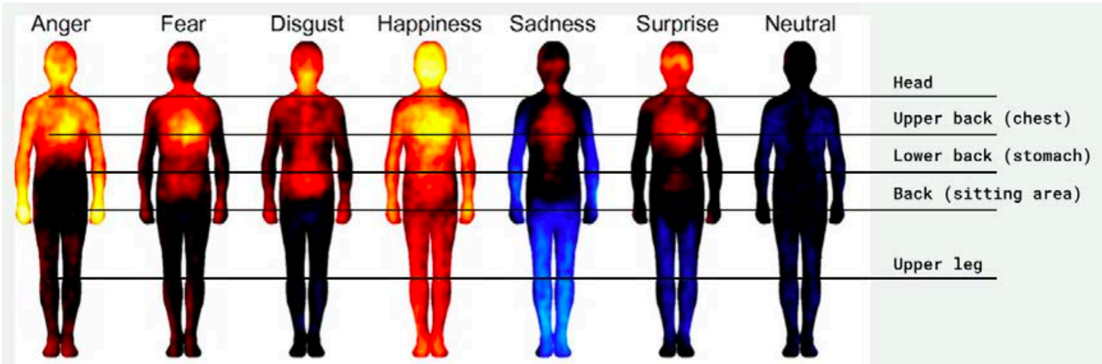


Figure 3.7 Heat Map of Bodily Reactions (Nummenmaa et al. 2014)

3.2.1 Haptic Implementation

For the vibration pattern, we wanted to create a rich tactile experience in which vibration is felt to move smoothly or in a continuous movement instead of discrete movement. In order to create the illusion, we followed the principles of higher physiological perception of human tactile sensations such as apparent tactile motion and phantom tactile sensation, stated by G.K.Essick (Essick 1998).

Apparent tactile motion

Apparent tactile motion (Figure 3.8) is a tactile illusion that observed when two vibrotactile stimuli were placed on the skin in close proximity and their actuation times overlapped. The result of this positioning is that the user would not perceive two actuators to vibrate separately, but rather a single actuator moving between them. This illusion creates the effect of continuous movement. However, the downside is that it only works for a certain distance between two actuators. If the distance is too far, it might break the motion illusion.

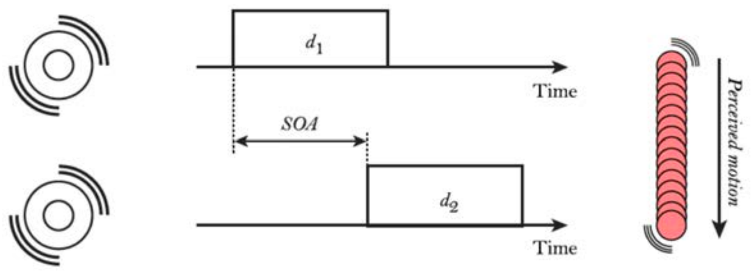


Figure 3.8 Apparent Tactile Motion (Israr and Poupyrev 2011)

Phantom tactile sensation

Another prominent tactile illusion is the phantom tactile sensation (Figure 3.9). This illusion is observed when a simultaneous stimulation of two nearby vibro-tactile actuators creates an illusion of a third vibrating actuator located between the real actuators. Compared to the apparent motion, the phantom sensation is static, and no motion is perceived.

The location of the illusory actuator can be controlled by changing the intensities of the two real actuators (e.g., if the intensities of both actuators are equal, the perceived illusory actuator will appear in the midpoint between them). The ability to place virtual actuator anywhere between two actuators allows the creation of smooth movement and makes phantom tactile sensation a stronger concept than apparent motion.

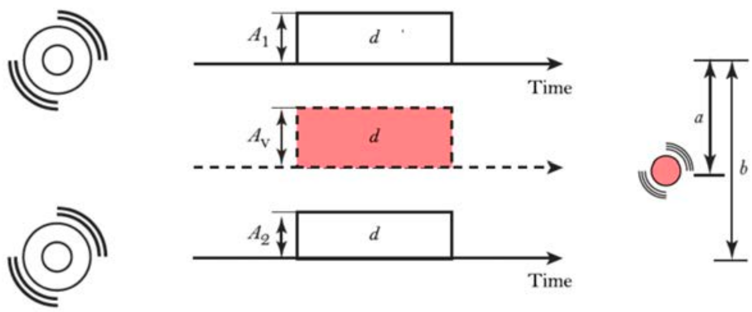


Figure 3.9 Phantom Tactile Sensation (Israr and Poupyrev 2011)

In this thesis, we decided to apply the phantom tactile sensation by following similar techniques to the Tactile Brush (Israr and Poupyrev 2011) study to achieve the illusion of continuous moving vibration.

We used a node function in MAX/MSP [2], which interpolates data graphically. The function consists of a knob and nodes (Figure 3.10). The node represents the actuator location, and its size indicates the actuator's vibrating range. Knob acts as the point that moves between actuators, and its location controls the interpolated weight of each active node. **The knob is equal to the illusory third actuator.**

This function enables us to automatically control the strength of two actuators when vibration moves from one to another, hence resulting in the phantom tactile

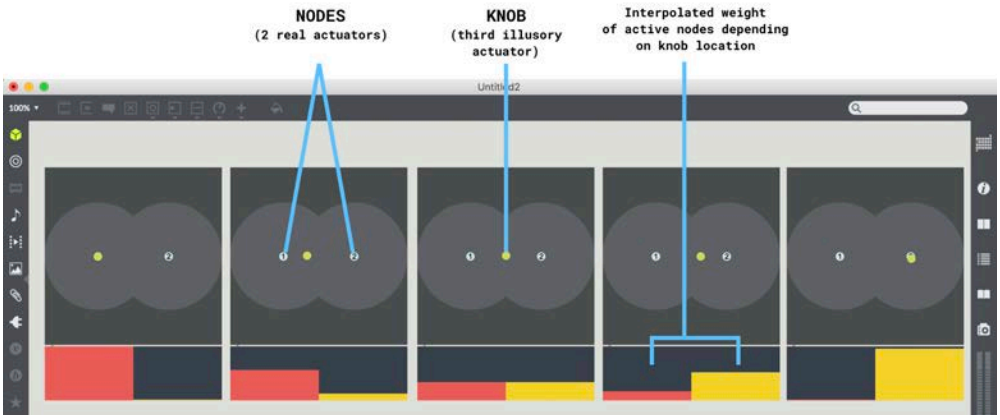


Figure 3.10 Nodes Function in MAX/MSP

sensation. Finally, in the actual implementation, we matched the position of the nodes to the actuator location on the chair, as seen in Figure 3.11.

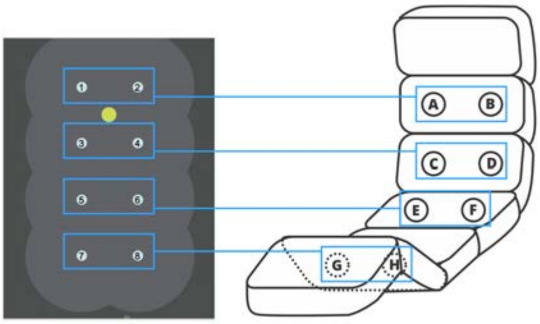


Figure 3.11 The Location of Actuators and Nodes are Matched

For the content of the vibration, we used amplitude-modulated sinusoidal vibrations as done in research (Yoo et al. 2015):

$$x(t) = Asin(2\pi F_e t) * sin(2\pi F_c t) \tag{3.1}$$

Where A, F_e, and F_c denote amplitude, envelope frequency and carrier frequency respectively.

3.2.2 Technical Implementation

We used 8 Vibro Transducer Vp6 Series[3] (16 Ohm, 5W)(Figure 3.12) and embedded them in an off-the-shelf cushion which was 55cm x 174cm as shown in Figure 3.13. We then connected them with 4 Lepy Amplifier LP2020A[4] and 1 Roland Audio Interface OCTA CAPTURE[5] to receive the audio signal from the computer.

Figure 3.12 Vibro Transducer Vp6

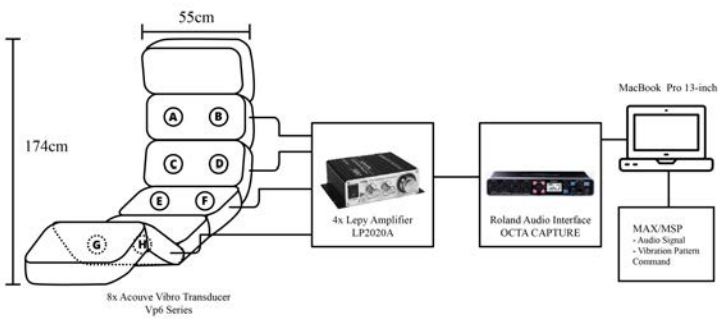


Figure 3.13 Components of Affective Haptic Chair System

Notes

1 https://www.quill.com/blog/careers-advice/public-speaking-is-scary-heres-how-to-get-over-your-fear.html

2 https://cycling74.com/

3 http://www.acouve.co.jp/product/pd_vp6.html

4 www.amazon.com/Lepy-LP-2020A-Digital-Amplifier-Stereo/dp/B00C2P61FO

5 https://www.roland.com/us/products/octa-capture/

Chapter 4

KAN.KA: Study and Evaluation

4.1. Overview

To evaluate KAN.KA concept, we conducted a two-part study: (1) designing and mapping the moving vibration patterns with emotion and (2) assessing the effectiveness of the vibration patterns to regulate emotion when people were performing a task. The second part of the study was conducted through an activity of reading a book. In addition to the two-part study, we exhibited KAN.KA in a "Positive Aging" demo day and managed to gain valuable insights of how KAN.KA application can be extended beyond emotion regulation solution in a cognitive task.

4.2. Study 1: The Effect of Vibration Patterns

The purpose of study 1 is two-fold. First, we want to design vibration patterns that generate various emotions in which we could use them to regulate emotions in the second study. Second, we want to evaluate the ability of across-body vibrotactile feedback to communicate an affective state.

4.2.1 Study Design

Method

In order to design and evaluate the vibration patterns, we followed the **"Generate, Select and Verify"** method as done with the mid-air haptics research (Obrist et al. 2015). This process divides complex tasks into a number of generate and review stages to produce reliable results. As evaluating emotions is a complex and subjective task, this method will help us to produce valid outcomes by comparing results from different groups of participants. Three different groups of participants underwent this process.

- **Generate Stage**
  A group of participants designed vibration patterns to represent five basic emotions.

- **Select Stage**
  A group of participants selected the best two out of five patterns, generated in the 'Generate Stage', to represent each emotion.

- **Verify Stage**
  A group of participants verified the selected patterns from 'Select Stage' if they matched the intended emotions.

Our hypothesis is *"If the vibration pattern-emotion pair identified by 'verify group' is consistent with the pairs selected by the 'select group' then we can say that directional vibration patterns across body are effective in inducing the desired emotions."*.

Audio as Emotional Stimuli

A previous study on human emotion by Gatti et al. reported that several external stimuli could elicit an emotional reaction which ranging from visual to olfactory stimuli (Gatti et al. 2018). Moreover, many of the standardized databases of these stimuli have been made available for research purpose. For instance, in mid-air haptic research, Obrist used images taken from the International Affective Picture System (IAPS) [1] to induce basic emotions (Obrist et al. 2015). Mood Glove (Mazzoni and Bryan-Kinns 2016), on the other hand, used short video clips taken from Emotional Movie Database (EMDB) [2] as the intermediary. As for our study, we used audio clips that were taken from MedieVal Database for Analysis in Music (DEAM) (Aljanaki et al. 2017) as the trigger to get users into a specific emotional state.

The selection of the songs followed the circumplex model developed by Russell (Russell 1980) (Figure 4.1). This treatment resulted in 4 quadrant combinations with the center being defined as the 5th neutral state.

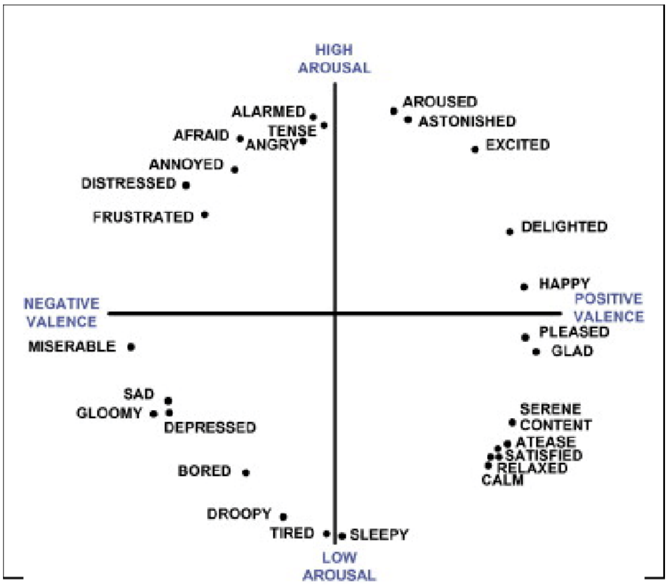


Figure 4.1 Russell's Circumplex Model of Affect (Russell 1980)

From DEAM dataset, we selected 5 audio clips with ratings which matched Russell's five combinations of valence and arousal as shown in Table 4.1. The values in the DEAM dataset are the average annotations for the whole song.

Song No	Song ID	Valence	Arousal	Emotive Keywords
01	115	8.4	7.8	Positive, Exciting
02	126	5.1	6.1	Positive, Calming
03	1902	4.4	7.3	Negative, Nervous
04	379	1.9	2.9	Negative, Sad
05	1812	5	5	Neutral

Table 4.1 Selected five songs with different combinations of valence and arousal values from the DEAM.

Self-Assessment Manikin for Emotional Rating

Any emotional stimuli used to elicit emotion is supposed to impact on participant's cognitive and physiological state (Bradley and Lang 1994). Hence, there have been several assessment techniques developed to measure those impacts. Two notable examples are the Self-Assessment Manikin (SAM) (Bradley and Lang 1994) and the Geneva Emotion Wheel (GEW)[3].

Self-Assessment Manikin (SAM) is a non-verbal pictorial assessment technique (Figure 4.2) to assess emotional state based on valence, arousal, and dominance value.

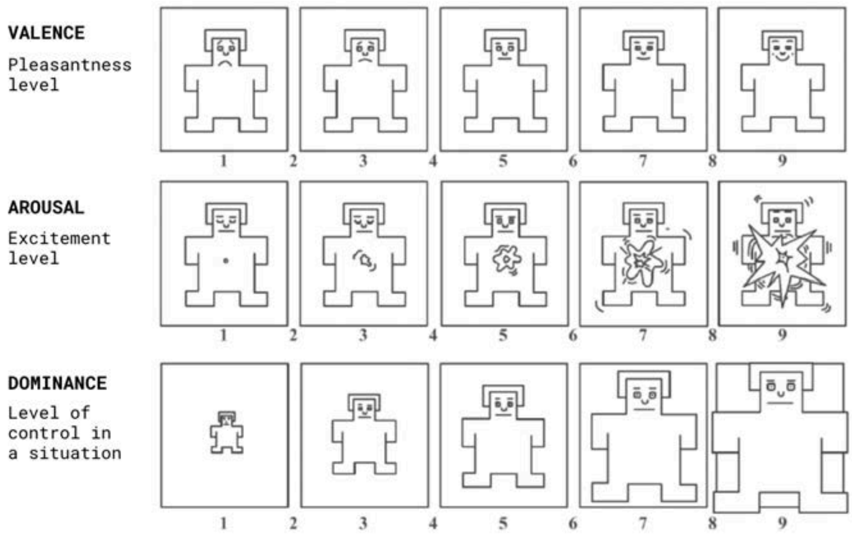


Figure 4.2 Self-Assessment Manikin (Bradley and Lang 1994)

Valence value represents the pleasantness level of the emotion, ranging from a smiling, happy figure to a frowning, unhappy figure. The arousal dimension indicates the level of excitement, ranging from an excited, wide-eyed figure to a relaxed, sleepy figure. Finally, the dominance dimension represents changes in control with changes in the size of SAM: the large figure indicates maximum control in the situation.

As opposed to the Geneva Emotion Wheel test, which gives participants 20 words of emotions to select from (Figure 4.3), the SAM test does not induce bias towards the selection or limit participant's emotional expression as there is no list of the emotive word presented on the paper. Therefore, we used **Self-Assessment Manikin** to record participants' emotional rating.

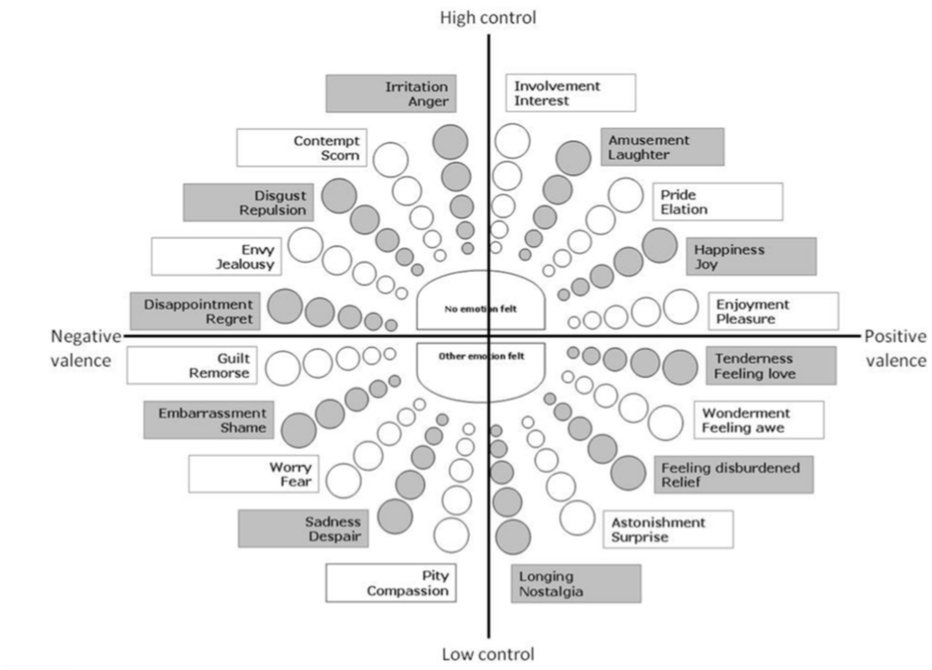


Figure 4.3 Geneva Emotion Wheel (Shuman et al. 2015)

4.2.2 Procedure

In total, 24 adult participants (15 female and 9 male) took part in the study. The study was conducted in a room in an academic department. The room contained a set of table and chair where the observer sits, KAN.KA furniture where the participant sits and a chair to put the laptop that runs the test. A headphone was provided for participants to listen to audio tracks for emotional stimuli. At the start of the test, participants were briefed on the experiment and signed a consent form. The overview of the process is as shown in the following diagram (Figure 4.15):

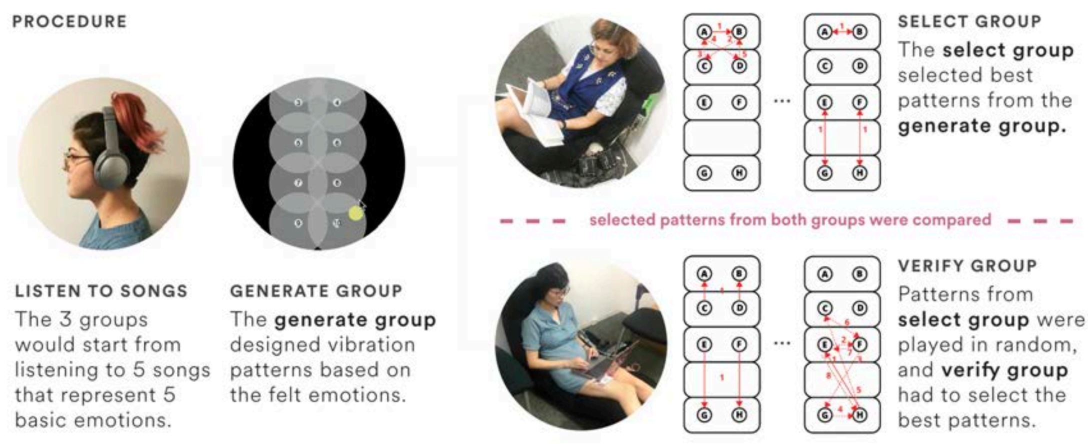


Figure 4.4 Generate-Select-Verify Process

Generate Stage

In the first stage, a group of 5 participants had to design vibration patterns for 5 different emotions. Each participant would listen to the five selected songs in a random sequence, one song at a time. After every a song, they would be asked to rate their emotional level by using Self-Assessment Manikin (SAM).

After rating their emotional level, they would be required to design the vibration pattern according to that particular emotion. The participants were instructed to design the vibration patterns after listening to the songs. This requirement was done to avoid the influence of song elements (e.g., beat, rhythm and so on.) when designing the vibration patterns.

After the initial explanation, participants of the **generate stage** were asked to sit on the affective haptic chair and they were given some time to become accustomed to the system. On the system interface, they were presented with eight nodes that represented the actuator locations on the chair. They could click and drag around the circle knob to experience how the vibration would flow from one node to another. They were also allowed to adjust the vibration frequency (60, 100, 150, 200, 300 Hz) and the number of pulses which was the envelope frequency (0, 1, 2, 4, 8, 16 Hz) in equation 3.1. The interface was shown in Figure 4.5.

Concerning the design requirement it could be summarized as follow:

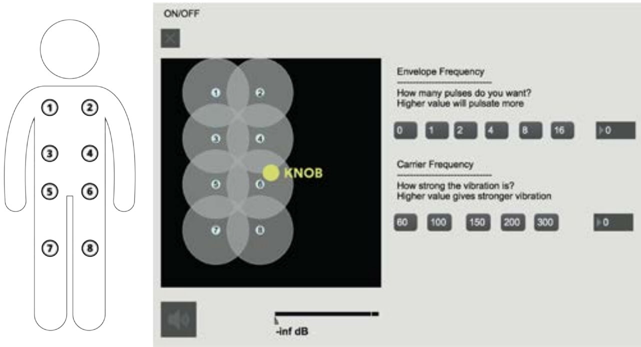


Figure 4.5 Vibration Pattern Design System Interface

- Participants could choose up to 8 nodes to represent the vibration movement. They had to write them in a sequence of how the vibration moved, and it could go back to the previous node. (e.g. 1-2-3-2-3-1)
- Participants could design the pattern as a continuous or non-continuous movement. Example for non-continuous movement would be vibration flowed from node 1 to 2 then jumped to 8 to 7.
- At the end of the design, participants were asked to describe the movement design in a sentence. (e.g. moves like an ocean wave)

At the end of the first stage, we obtained 5 patterns for each emotion resulting in 25 vibration patterns in total. The following figures (4.6, 4.7, 4.8, 4.9, and 4.10) show the patterns and the description of how users made a connection between movement and emotions.

SONG 01: Valence Positive / Arousal Positive

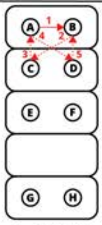
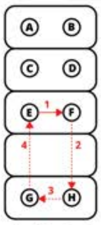
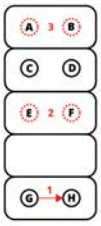
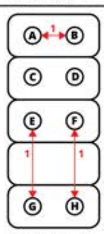
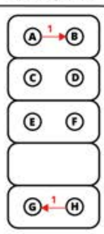
Name	Haptic Description	Affective Design Description
1A	 Fc=60 ; Fe=16	I designed this pattern to represent feeling of annoyance. When the strong pulse or vibration hits me, I feel uncomfortable.
1B	 Fc=150 ; Fe=2	I would like the vibration to run through my body (from back to leg) similar to the feeling of running, dancing or moving a bit, but not jumping.
1C	 Fc=150 ; Fe=4	The feeling is like a shy person who has a strong desire to dance. It feels like a dance party on a cruise ship.
1D	 Fc=100 ; Fe=4	This feeling makes me want to move with the beat. I designed the vibration to have a toe-tapping swinging beat to it. The vibration happily rocks back and forth.
1E	 Fc=200 ; Fe=4	The feeling is a mixed of fun and blues. I designed the vibration to mimic a shuffling movement.

Figure 4.6 Patterns for Song 1: Valence Positive and Arousal Positive.

SONG 02: Valence Positive / Arousal Negative

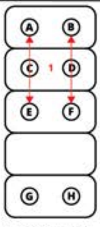
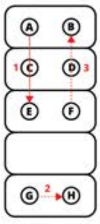
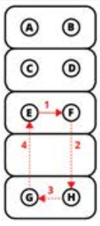
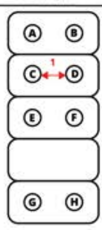
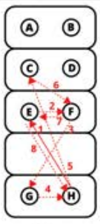
Name	Haptic Description	Affective Design Description
2A	 Fc=300 ; Fe=16	I designed this pattern to mimic bouncing body. The movement is like a swing.
2B	 Fc=100 ; Fe=2	The feeling made me think of twirling or moving up and down at a large ball-room hall. While, dances are joyous, there is an air of sadness or rejection. I represented this with the vibration on the legs area.
2C	 Fc=150 ; Fe=1	The feeling is like winds in spring season.
2D	 Fc=300 ; Fe=1	It feels like breeze in the late spring or the feeling of playing on the swings in late summer.
2E	 Fc=200 ; Fe=2	It is a happy and relaxing feeling. I think of the an-cient Europian dance party and I would like to feel the rhythm. I focused on the lower part of body be-cause vibration on upper body disrupt the joy.

Figure 4.7 Patterns for Song 2: Valence Positive and Arousal Negative.

SONG 03: Valence Negative / Arousal Negative

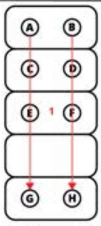
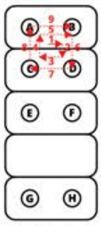
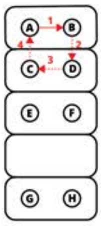
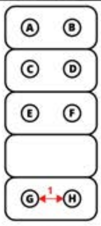
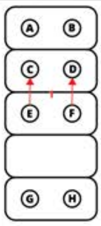
Name	Haptic Description	Affective Design Description
3A	 Fc=300 ; Fe=16	It is a calming emotion. When I am aware of my entire body I feel calm, hence I designed the pattern to vibrate across the whole body.
3B	 Fc=200 ; Fe=0	It feels mysterious with an air of sadness and anxiety. The pattern I felt reflected this idea of someone just slowly drag their fingers on one's back. The slowness reflecting the sadness but the spiraling circle providing a bit of uncertainty.
3C	 Fc=200 ; Fe=2	It feels sad and serious. It is like something serious would happen soon in and old movie.
3D	 Fc=300 ; Fe=1	I feel calm, sad and quiet. It reminds me of cloudy day near the seaside. I don't want to get interuppted from being sad so I focus the vibration on my lower body.
3E	 Fc=60 ; Fe=0	It is a slow tornado that is mustering inside your stomach.

Figure 4.8 Patterns for Song 3: Valence Negative and Arousal Negative.

SONG 04: Valence Negative / Arousal Positive

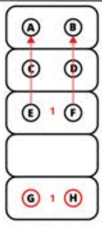
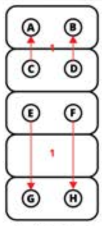
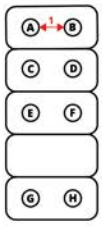
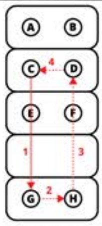
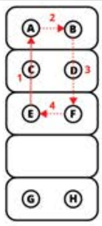
Name	Haptic Description	Affective Design Description
4A	 Fc=300 ; Fe=16	It is a mixed of excitement and anger feeling. It is like the emotion is exploding or rising.
4B	 Fc=100 ; Fe=4	I thought of concentrating the vibration in the center to remind me of bottling up emotions. But then as I start to accept the change I want to release the emotion, the vibration gradually spread to all directions.
4C	 Fc=60 ; Fe=2	It is annoying. It feels as if someone's shouting to my ear.
4D	 Fc=100 ; Fe=8	I feel anxious and can't stop, hence I designed the vibration patterns to move all the time across my body.
4E	 Fc=150 ; Fe=2	It is like when I'm driving fast and my emotion is bursting. The vibration goes from the bottom of my back to my heart to expressd the burst.

Figure 4.9 Patterns for Song 4: Valence Negative and Arousal Negative.

SONG 05: Neutral

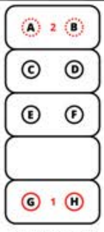
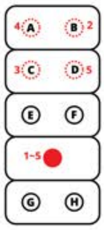
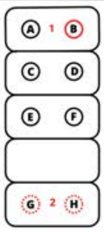
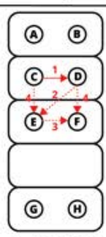
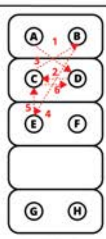
Name	Haptic Description	Affective Design Description
5A	 Fc=300 ; Fe=16	It is a harmonious and happy feeling.
5B	 Fc=300 ; Fe=1	It feels like love. As love starts with an attraction hence I designed the vibration to start at one point. Then, as I added random pop-ins to adds a level of positive excitement which I associated it with young love.
5C	 Fc=200 ; Fe=1	It is like the feeling when you want to talk to your crush but he's taken by somebody.
5D	 Fc=300 ; Fe=2	The movement starts with a zig zag as if your emotion is increasing, and suddenly it goes down.
5E	 Fc=150 ; Fe=1	It is a relaxing and nostalgic feeling. The emotion is a bit melancholic.

Figure 4.10 Patterns for Song 5: Neutral.

Select Stage

A second group of 10 participants was asked to select 2 out of 5 vibration patterns (per emotion) that best matched the intended emotion. First, they would listen to the selected 5 songs in random sequence. After every a song, they would rate their emotional state using the SAM survey. For each emotion, 5 patterns designed in the previous group would be played in random sequence, and participants were asked to rate them on a Likert scale from 1 to 5 according to the appropriateness to represent the intended emotion (5 corresponded to the most appropriate pattern, and 1 was the least appropriate). From this round, we took ten vibration patterns to be verified in the next stage.

Verify Stage

The third group of 9 participants was asked to listen to the 5 songs in random sequence. With the same procedure, they had to rate the emotional state after listening to every song. For this round, the 10 vibration patterns selected from the previous group were all played in random sequence for each song. They would have to rate the 10 patterns on a Likert scale from 1 to 7 according to the appropriateness to represent the intended emotion (7 corresponded to the most appropriate and 1 was the least appropriate).

At the end of each test session, each participant was interviewed with questions regarding the experience.

4.2.3 Results and Discussion

We analyzed all the data collected from the three groups. First, we compared the SAM results with the DEAM valence and arousal values, and found they both matched each other across all three groups. These outcomes ensured that the design and selection of vibration patterns were based on the intended emotions.

Then, to evaluate the ability of across body vibrotactile feedback to induce emotions, we compared the results from the 'verify' group and 'select' group. Our hypothesis was that: "If the across-body haptics were indeed effective in communicating emotions, then the 'verify' group would rate the patterns selected by the 'select' group as the most appropriate pattern to represent the intended emotion." Following this comparison, we also conducted further statistical tests on the results obtained from the 'verify' group.

To conclude, we also categorized insights from the interview based on common themes that kept appearing in the transcript.

Selecting and Verifying Patterns

We compared the selected patterns by the **select group** and **verify group** to test our hypothesis. From the 25 patterns created in the **generate stage**, 10 patterns were selected by the **verify group** as shown in Figure 4.11.

	Song 1 (+ valence + arousal)		Song 2 (+ valence - arousal)		Song 3 (- valence - arousal)		Song 4 (- valence + arousal)		Song 5 (neutral)	
Pattern No.	1C	1E	2A	2B	3A	3B	4B	4E	5B	5D
Appropriateness points	34	35	37	31	45	39	36	36	32	33
No. of times selected as top 2	6	6	8	5	8	6	7	6	7	6

Figure 4.11 10 Patterns from Select Group

Participants in the **verify group** then rated the selected ten patterns. Our hypothesis held as the results we obtained revealed that all emotions, except emotion from Song 02, did match again with the pattern that had been chosen from the selection stage (Figure 4.12).

	Song 1 (+ valence + arousal)		Song 2 (+ valence - arousal)		Song 3 (- valence - arousal)		Song 4 (- valence + arousal)		Song 5 (neutral)	
Pattern No.	1C	1E	2A	2B	3A	3B	4B	4E	5B	5D
Appropriateness points	46	42	31	30	47	49	42	36	41	40
No. of times selected as top 2	7	3	2	2	3	6	6	2	5	3

Figure 4.12 4 out of 5 emotions were matched with the intended patterns

Song 02 (positive valence and negative arousal) which was intended to be a happy and calming emotion was found to be the most difficult to match. Continuously users chose the pattern designed for Song 05 instead. However, when the users from **verify group** were interviewed, many expressed in words that both Song 02 and Song 05 induced similar emotional characteristics. Assuming participants perceived Song 02 and Song 05 to have the same emotion, then by selecting the same vibration pattern for both songs proved the hypothesis.

Data Analysis

We conducted data analysis of the results obtained from the **verify group** to ensure that each pattern was rated differently depending on the emotion stimuli they were presented with. This test was done to verify the validity of the across-body haptic in conveying emotions.

We conducted a two-way ANOVA to examine the effect of the five selected songs and the vibration patterns on the appropriateness ratings. The outcome suggested a statistically significant interaction between the displayed songs and the vibration patterns (F = 4.728, p ¡ 0.001). Simple main effects analysis was performed to understand the interaction better. The results showed that the displayed songs significantly affected the appropriateness rating (p = 0.003), but there was no effect from the vibration patterns (p = 0.07).

The ANOVA result showed that participants rated each vibration pattern differently depending on the displayed songs and they tended to score the pattern higher when it reminded them of the songs. Figure 2.9 shows the differences in the vibration pattern ratings.

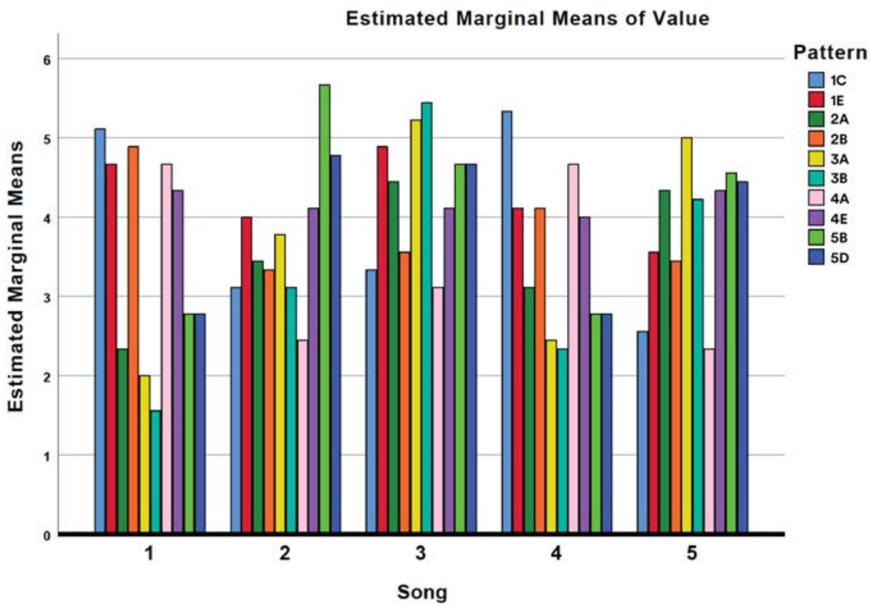


Figure 4.13 The differences in the rating of each pattern towards different songs.

The patterns which are intended to represent each respective song were marked in a sequence (Song 01 - patterns 1C,1E; Song 02 - patterns 2A,2B, and so on). When we presented a pattern with the song it was intended for, participants tended to rate it higher. This result shows the possibility of using across-body haptic to convey emotions. However, for further clarification, we would add physiological measurement in the test as our future work.

Qualitative Feedback

In this section, we discuss the common themes that kept appearing in the interview transcript which we find useful for designing vibration patterns in our future study.

- **Actuator Location Effect towards Felt Emotions**
  During the **generate stage**, when we asked participants to design the pattern for Song 01, 4 out of 5 perceived that the lower part of the body towards the leg area was the best region in which to describe a positive valence and positive arousal type of emotion such as happiness or excitement. *"I feel like running or dancing. Hence I would like the vibration to run along my lower back to my leg."* Another participant also mentioned that the emotion felt was positive and upbeat hence their vibration design moved in a swinging motion up and down from the lower back to leg area with a staccato pulse.

  For inducing a happy and calming emotion (positive valence and negative arousal value), participants preferred to design the pattern as gentle movement on their shoulder area, as they felt it was similar to the tapping a mother does to her baby to calm it. Whereas for negative valence or a feeling of annoyance, most participants felt vibration around the lower back area would induce such an emotion.

  In the **select and verify stage**, we also asked the participants to associate different body parts with the emotions. Comments made by the participants during these two stages were similar to those brought during the **generate stage**, such as *"the vibration on the upper part made me feel either sad or stable, whereas the vibration on the lower part made me felt happy and uplifting."*.

  These various comments suggested that feelings of positive valence could be achieved in both upper and lower part of the body. Hence it is accurate to say that the actuator location is exceptionally relevant in designing different arousal levels. These findings on the effect of actuator location towards emotions would be useful in designing our next study.

- **Directional Parameters, Continuous vs Non-Continuous Movements**
  We also found that the direction and the type of movement could influence the elicited emotions. The most apparent directional parameters for movement across the body would be up and down. To induce a positive valence emotion, we could design the vibration to flow from the leg area to the shoulder area. Whereas for a calming emotion, the vibration should flow in the opposite direction from top to bottom. However, we found that the left and right directional movements did not have any effect on the perceived emotion.

  Moreover, continuous movement, in which the vibration moved from one node to another without any break, could be used to induce negative arousal type emotions. One example was a circular movement in pattern 3C for Song 03. On the other hand, a non-continuous movement was often seen used in designing patterns for emotion with higher arousal such as the popping vibration used in pattern 1C of Song 01.

Overall, our findings suggest that the vibration patterns match well the intended emotions. Hence, we possibly could use this system as a way to regulate unwanted emotions by providing the desired one. During the interview, actuator location and directional parameter were observed to play a vital role to generate a different type of emotions. These insights provide an initial basis for exploring the design of affective furniture for emotion regulation.

4.3. Study 2: KAN.KA in Reading Activity

In this second part of the study, we will be assessing the effectiveness of the vibration patterns to regulate emotion when people were performing a task. As mentioned in the earlier chapter that while performing a cognitive task, for example, reading a book, there is a chance where an internal emotional distraction might disrupt our reading performance. Hence, in this section, we would like to put our solution into the test by applying it as a "Situation Modification" strategy.

4.3.1 Study Design

Vibration Patterns to Test

From the previous study, we were able to discover four vibration patterns which matched up with four types of emotions (a neutral emotion, represented in Song 5, was eliminated due to its ambiguity). The four patterns were [Song 01 - Pattern 1C; Song 02 - Pattern 3B; Song 04 - Pattern 4B; Song 05 - Pattern 5B], as illustrated in Figure 4.14.

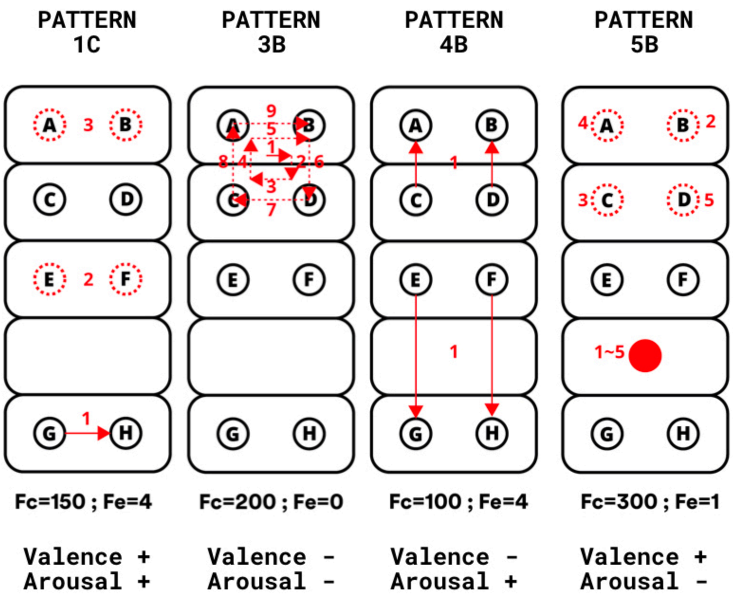


Figure 4.14 Final 4 patterns that represent basic emotions

We will be using these final four patterns in the test.

Method

In order to test the effectiveness of the vibration patterns, we designed a reading comprehension activity as a distractor test. The distractor test works to engage users in an activity, hence, diverting users' attention from the vibration patterns. We have five experimental conditions as follow:

- *Control Group condition*: participants read an article and answer some questions related to the content without any vibration.
- *Pattern 1C condition*: participants do the same tasks with the control group, but in the middle, they would experience vibration pattern 1C.
- *Pattern 3B condition*: participants do the same tasks with the control group, but in the middle, they would experience vibration pattern 3B.
- *Pattern 4B condition*: participants do the same tasks with the control group, but in the middle, they would experience vibration pattern 4B.
- *Pattern 5B condition*: participants do the same tasks with the control group, but in the middle, they would experience vibration pattern 5B.

4.3.2 Procedure

Participants in this user study were asked to perform a reading task while sitting on KAN.KA furniture. Each participant would be given a set of reading articles taken from British Council learning website [4]. The level of difficulty was adjusted according to the participant's English level.

To begin with, participants were told that the purpose of this research was to assess the emotion being induced by the vibration pattern and the reading task was to be used to divert their attention from the pattern. The activity was divided into five sessions, and each session lasted for 5 minutes. After every completed session, there would be a break for the participant to fill out a SAM questionnaire, which they used to rate their emotional level (Figure 4.15).

During the first session, no vibration pattern was administered. The participants were informed, however, that after the first session, there would be some vibration playing from the cushion while they performed the remaining four sessions. The vibration would begin playing in the middle of the session and would continue until the end. The sequence of the vibration patterns was randomized.

Finally, at the end of the test session, participants were asked to share some feedback regarding the application of KAN.KA.

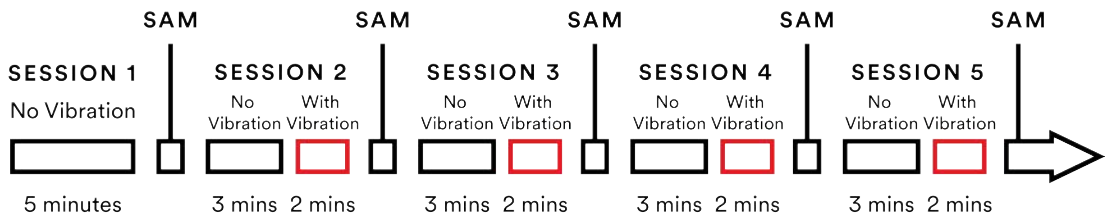


Figure 4.15 Reading comprehension activity breakdown over 5 sessions

4.3.3 Results and Discussion

Effects of Vibration Patterns towards Reading Activity

In this study we wanted to assess if the valence and arousal values were rated differently for each pattern, hence we applied the Friedman test for the analysis. For this experimental design, we had four different conditions, the 4 vibration patterns, and two variables (valence and arousal) to be evaluated.

The Friedman test results showed that there was no significant difference in the rated valence value dependent from the vibration pattern which played while the participant read an article. However, there was a significant difference in the arousal value (Arousal: $X^2(2) = 8.440, p = 0.038$). The standard deviation of each pattern was shown in Figure 4.16.

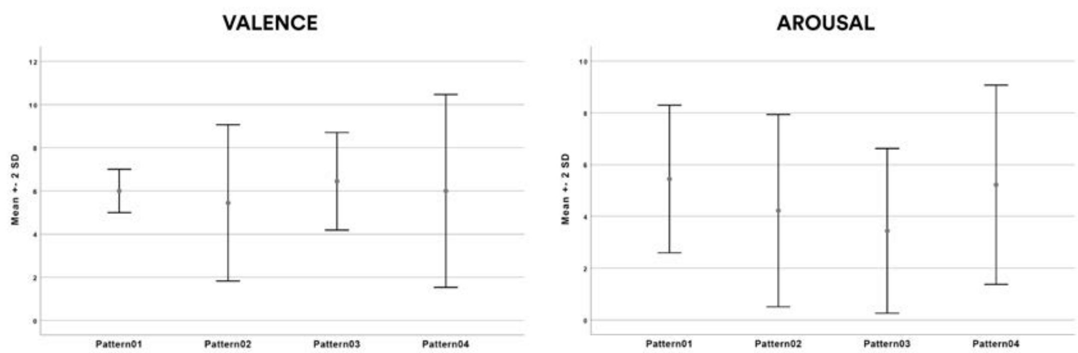


Figure 4.16 Mean and Standard Deviation value for Valence and Arousal of each pattern

The results of this test informed us that the moving vibration pattern only affected participants' arousal value and did not influence the valence value. During the interview, participants mentioned that depending on the vibration pattern, they would feel either calm or nervous, but did not have any feelings of either happiness or sadness. One possible explanation was that the content of the article had a more significantly captured the users attention more than the vibration.

Qualitative Feeback

From the interviews conducted during our second study, some participants mentioned that the vibration movement pattern not only influenced their reading concentration, but also opens up new design opportunities to use the patterns in other activities. In this section, we describe three ideas for applying emotive moving vibration patterns in daily life activities (Figure 4.17).

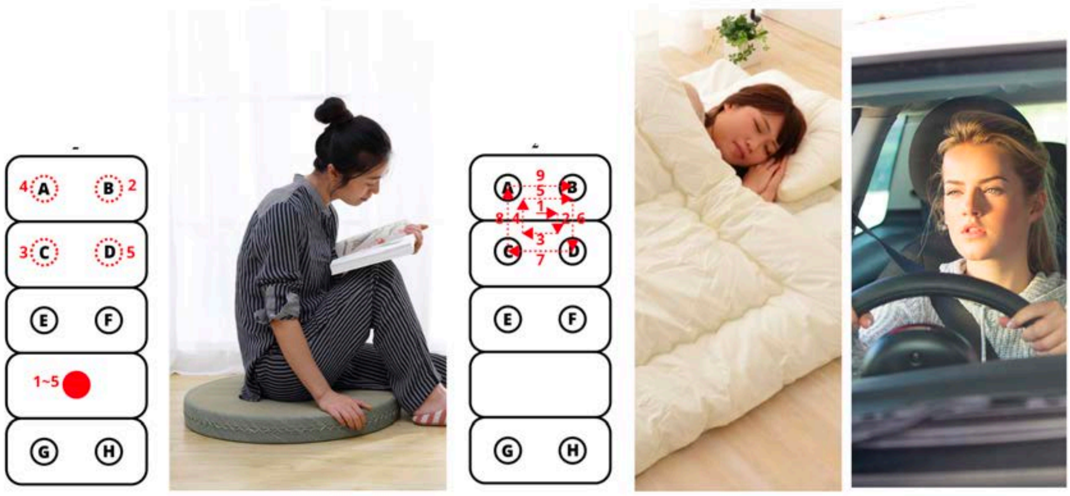


Figure 4.17 Design Opportunities for KAN.KA

- **Reading Activity**
  When the pattern was a continuous movement, they were able to focus more on the reading. On the other hand, they felt that at first, the non-continuous movement was a distraction from their reading, however, as they continued reading they noticed that if they felt the vibration occurrence was

related to the content of the article it actually helped them to be focused and enhanced the emotional experience. This comment suggested a possibility to use moving vibration pattern to enhanced emotional feelings while reading, a concept similarly proposed by the FeelSleeve (Yannier et al. 2015), a haptic mobile interface that allowed children to feel story events in their hands.

- **Sleeping Activity**
  Another possible application of the affective haptic chair would be for sleeping or relaxation activities. Participants mentioned that some vibration pattern felt very relaxing while others made them feel rushed or anxious. Different patterns could be played at different intervals during the sleep process. For instance, a relaxing pattern could be used to help people calm down and fall asleep more quickly. While a vibration pattern with a higher arousal value could be used to make a person feel more excited and help them to wake up in the morning.

- **Driving Activity**
  Additionally, regulating stress while driving has become a growing topic in the area of affective technology. MacLean et al (MacLean et al. 2013) explored the use of actuated wing motion to reflect a driver's real-time stress state. The wing motion acted as an early-stress-warning system. However, the result showed that the visual feedback of MoodWings (MacLean et al. 2013) became a stressor to the drivers instead. While this study was unsuccess in reducing stress. It raises the possibility that perhaps leveraging moving vibration patterns to induce a calming emotion through the driver's seat could be the answer. Moving vibration patterns have the potential to be an alternative way to regulate a driver's stress in a subtle and less distracting way as compared to the visual feedback.

These are just some suggestions in which mapping moving vibration patterns can be applied towards designing affective haptic furniture. Further furniture formats that are also worth exploring are a bed, a car seats, or various types of office furniture. With such simple daily life applications have the ability to potentially improve the quality of life of users but either allowing them to reduce stress or providing them with an enhanced feeling of entertainment.

4.4. KAN.KA for Positive Aging

During the study, we had an opportunity to exhibit our KAN.KA furniture in an assisted living home, Hyldemoer Hutte in Japan. Under the positive aging project, we saw an opportunity to use KAN.KA furniture to provide older adults with a positive emotional experience. The final goal is to improve their quality of life and well-being. During the exhibition, we managed to showcase KAN.KA to both the care staff group and the elderly people group, and gather insights on how this furniture can be further developed to meet their needs.

4.4.1 KAN.KA x Biophilia Concept

There are two initial goals in this project: (1) self-motivation, which is to instill positive emotion in the daily lives of the residents, and (2) expanding ability, which is to empower the residents to regulate their own emotion.

To achieve the first goal, we felt that pairing apparent vibration movements with natural sounds instills positive emotions into one's mind, inspiring them to improve their outlook. We focused on using natural sounds because human beings have the innate desire to be affiliated with other forms of life (Wilson 1985) or often called as *Biophilia Hypothesis*. Further studies also mentioned that nature powerfully engages the mind with "involuntary fascination," which helps to promote stress reduction and renewal (Kaplan and Kaplan 1995). Another report also confirmed that having views of natural elements like trees or water, increased the well-being of a workplace (Spaces 2018). Therefore, we felt that we could use audio-haptic technology to bring nature to the nursing/assisted living residents, and nature would serve as a means of motivation.

We then used three vibration movement patterns from Study 1 (**??**) and coupled each pattern with a nature audio clip. For one, we combined movement on the upper body (Pattern 3B) with the sound of a heartbeat. The second combined movement on the leg area (Pattern 2C) with the sound of an earthquake. Finally, we combined movement across the body (upper to lower) (Pattern 4B) with the sound of a waterfall. (Figure 4.18)

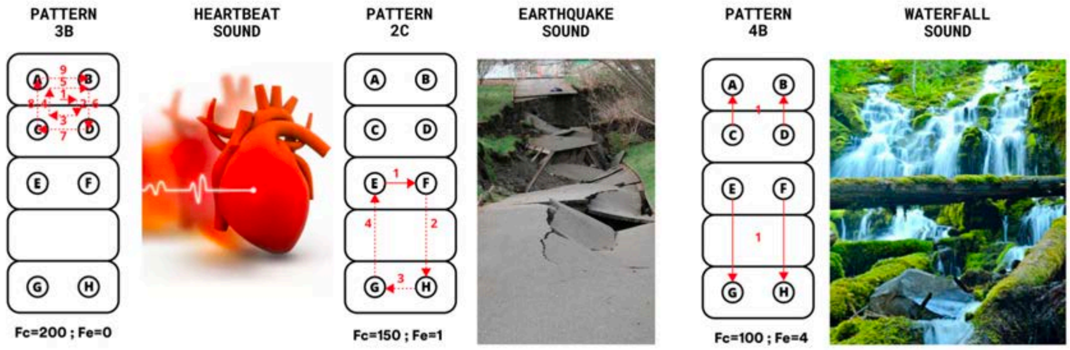


Figure 4.18 Vibration Patterns Paired with Nature Sounds

4.4.2 Feedback from the Community

- **Care Staff Group**
  We tested these audio-haptic combinations with six care staff members and collected their feedback (Figure 4.19). Concerning the experience, the care staff responded positively. Care staff members felt that as the vibration moved across the body, this helped make the experience felt more realistic and felt a connection to nature. They also felt that the selected body locations where the vibration moved matched well with the paired audio. Furthermore, the vibration movement across the body also enhanced induced emotions.

Figure 4.19 Care Staff Tried KAN.KA Furniture

For example, a majority of the care staff like the waterfall experience as they felt it helped them to regain a sense of calmness. One care staff member also mentioned that because the earthquake vibration moved around their leg area, they felt a strong sense of fear. These initial tests with care staff showed a positive result regarding emotion enhancement due to pairing natural sounds with apparent vibration movements, leading us to be optimistic that we will be successful in developing a chair that will aid in self-motivation and become a catalyst in expanding the nursing/assisted living resident's ability. However, we still need to carefully select suitable audio, vibration movement pattern, and the type of nature experience that we want to recreate to inspire positive emotions among the elderly people community.

- **Elderly People Group**
  We had 7 older participants experienced the KAN.KA x Biophilia system (Figure 4.20). They had been very positive about the experience and found that it helped them to get relax. The heartbeat sensation had the most interesting impact as one participant mentioned that she thought it was her heartbeat and helped her to stay calm. In contrast to the care staff group, the majority of the older participants prefer the heartbeat sensation.

  This finding leads to a design opportunity to incorporate monitoring sensors, which can sense the user's heartbeat. We could use the biofeedback to either trigger an appropriate vibration pattern-nature audio pair to regulate any detected negative emotion or have the chair mimic the user's real heartbeat. Either solution, we feel would enable the user to understand their emotional state better and empower them to regulate their own emotion, thus achieving our second goal of expanding ability.

Figure 4.20 Older Participants Tried KAN.KA Furniture

4.5. Summary

Our concept to help people regulating their emotions during their activity is to use directional vibration pattern that moves across their body. In order to prove the concept, we first need to ensure that the directional vibration patterns can induce different emotions. If the patterns can express different emotions, and if we can control when to play the patterns, then we can eventually regulate any unwanted emotions at any point in time.

Hence, in the first study, we tested the relationship between vibration pattern and emotion over three different groups of users. The results showed that the possibility of using directional vibration patterns to express different emotions. We managed to obtain four validated emotion-vibration pattern pairings. Moreover, we also gathered some insights into users' preferred vibration patterns.

Bringing the final four vibration patterns to the second study, we then tested their capability to influence emotions in a real-life scenario. However, the result showed that only the arousal value of emotion was influenced, whereas the type of task participants was doing then, more likely influenced the valence value. Despite the results, we managed to gather insights from the user interviews and pinpoints some area in which we can improve to increase the probability of influencing user's emotions.

In the last study, we had an opportunity to showcase our furniture to a group of older adults in an assisted living home. We managed to gather feedback from the community regarding the application of this furniture to promote positive aging.

In a broader context, the knowledge obtained can contribute to the inspiration to design a new type of affective furniture that helps to improve overall emotional wellness of a person, during an activity or as leisure time.

Notes

1 https://csea.phhp.ufl.edu/index.html

2 https://www.ncbi.nlm.nih.gov/pubmed/22767079

3 https://www.unige.ch/cisa/gew/

4 https://learnenglish.britishcouncil.org/

Chapter 5
Furniture Design Process

5.1. Concept Design

After going through different studies, it has become apparent that the design of KAN.KA furniture also plays an important role in regulating emotions. There are several aspects that we need to consider in designing good furniture, and they involve both functional and aesthetic aspects. We will break down the concept design into three different analysis: semantic, pragmatic, and syntactic analysis, based on a contemporary product design approach (Boucharenc 2008).

5.1.1 Semantic Analysis

Semantic analysis tries to see the relationship between the user and the product or describe the meaning of the product in a social context. It focuses on analyzing the product's purpose and its function. In his book, Boucharenc describes that semantic analysis consists of three points of view:

- **Context**: the situation in which the product is supposed to be used.
- **Form Analogy**: the comparison between the product and other objects with similar form or shape features and which are often used to explain a principle or concept.
- **Spirit**: the emotional response evoked by the product in general (for instance, an evoked notion of speed, sophistication, simplicity, etc.

In this section, we will use this analysis method and describes the meaning behind KAN.KA design. The following image shows the semantic elements that inspire KAN.KA furniture design (Figure 5.1).

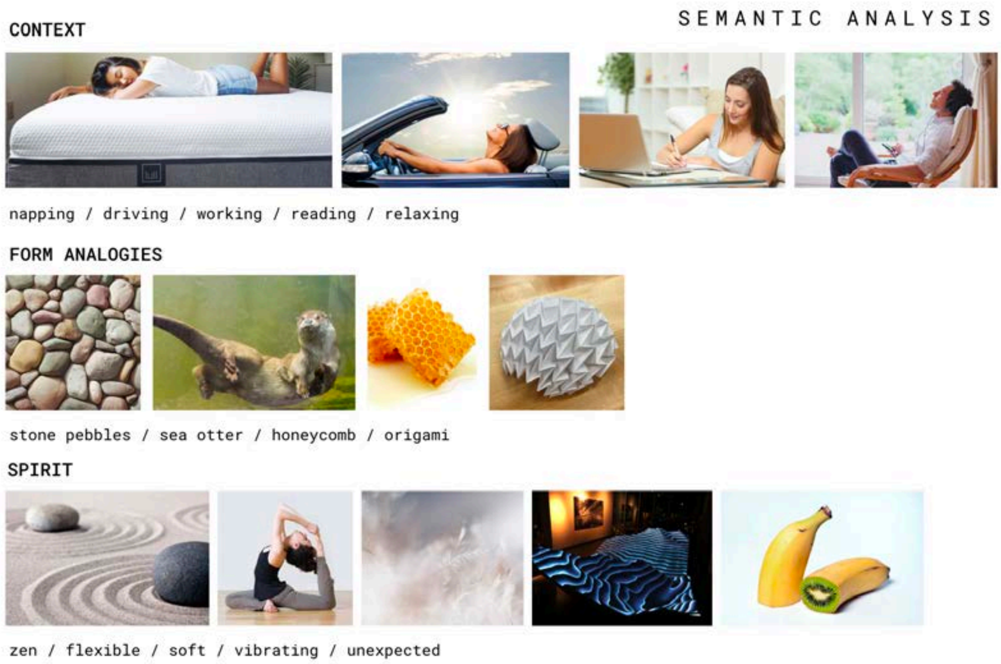


Figure 5.1 Semantic Analysis of KAN.KA Furniture

KAN.KA furniture can be used in a very diverse context, starting from a regular leisure chair, to an attachable cushion on driving seat. Aside from sitting situation, KAN.KA can also be used in a lying down position such as sleeping. With this functionality as a goal, we need KAN.KA to be flexible and modular, almost like a shape-changing form. Thus, we derived some inspirations from stone pebbles, honeycomb, or origami, which are easy to configure or stack according to the desired form. Then, to add flexibility, we look into how sea otter moves its body while swimming in the water. We hope that KAN.KA can be conceived into a bendable form.

In terms of the evoked emotion, as the primary purpose of KAN.KA is to regulate emotion and improve well-being; we looked into keywords such as zen and soft, which typically associated with comfortable or calming emotion. Furthermore, not only KAN.KA evokes comfort, and we hope KAN.KA could have a unique characteristic of inducing eye-opening experience to the user or inducing unexpected haptic sensation when the user's skin meet the materials.

5.1.2 Pragmatic Analysis

Pragmatic analysis looks in detail the function and ergonomics of the product. It focuses on analyzing how the product works or how it can be used.

In the following image, we will illustrate three ways of how KAN.KA furniture can be used (Figure **??**):

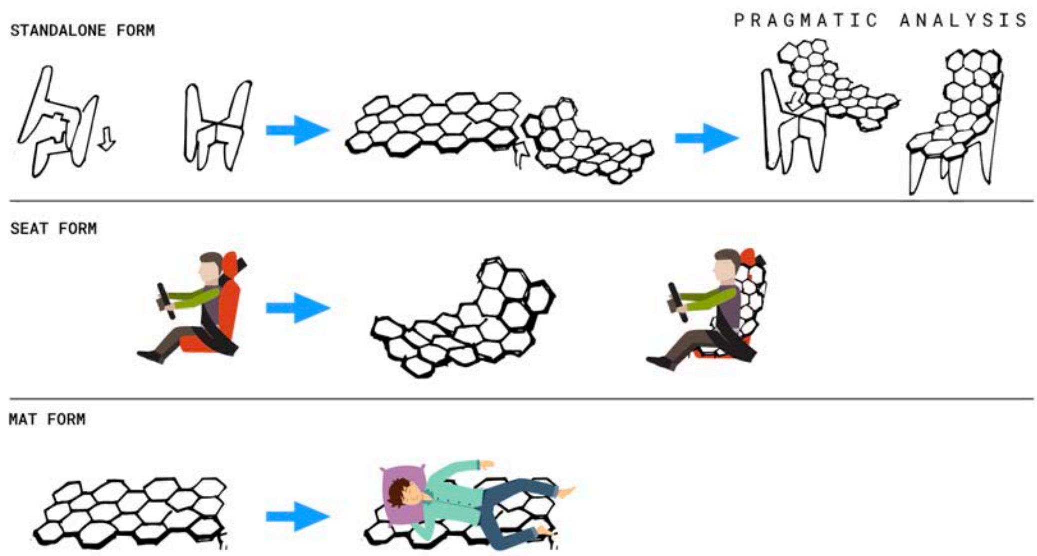


Figure 5.2 Pragmatic Analysis of KAN.KA Furniture

- **Standalone Form**: KAN.KA will come in a DIY model to allow the ease of making and bringing KAN.KA around. The independent form allows KAN.KA to be used even without any other furniture support.
- **Seat Form**: KAN.KA is a soft cushion that could follow the shape of other furniture. Hence users can always add KAN.KA on top of regular furniture.
- **Mat Form**: KAN.KA as it is can be used as a mat. It can support activity such as napping or sleeping.

5.1.3 Syntactic Analysis

Finally, syntactic analysis discusses how a product is built in terms of structure, component details, and respective materials.

For KAN.KA furniture, we have to look into materials and structure that are bendable or comfortable enough for sitting support, but at the same sturdy enough to hold user's weight. Furthermore, we also want to make KAN.KA as minimalist as possible and easy to be assembled by anyone.

The images on the next page are some examples of how we ideated the furniture form based on the above requirements (Figure 5.3):

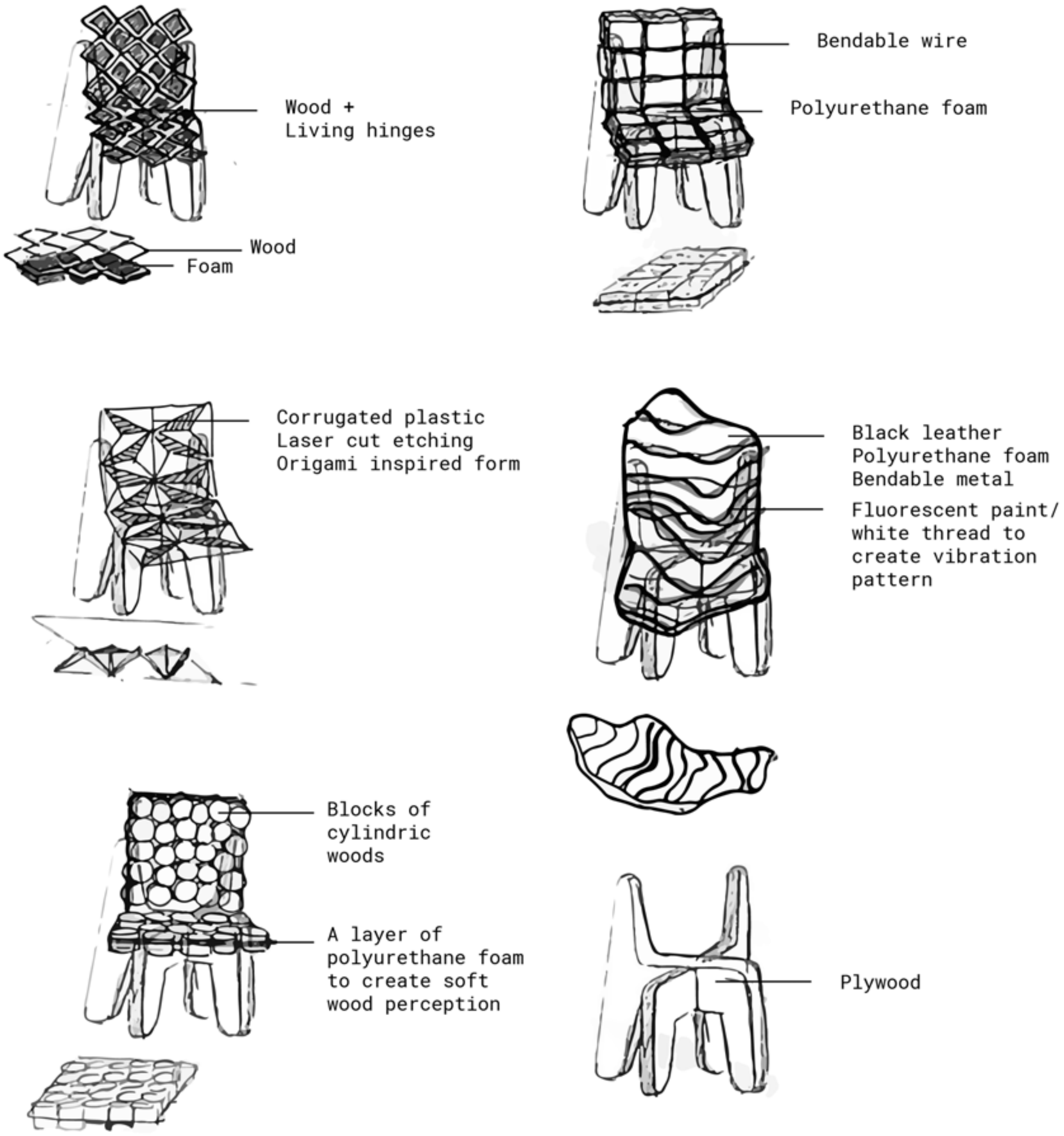


Figure 5.3 Syntactic Analysis of KAN.KA Furniture

5.2. Prototyping

The process of making KAN.KA furniture started from drawing sketches to building scale models and finally prototyping a to-scale object.

Image 5.4 shows the scale model of KAN.KA furniture.

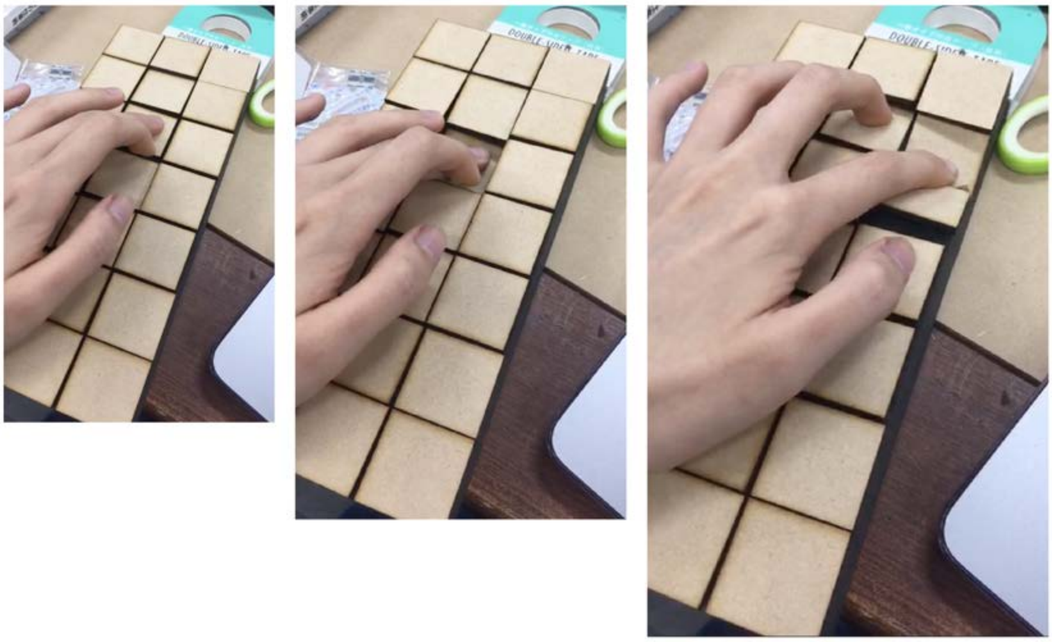


Figure 5.4 Scale Model of KAN.KA Furniture

In building the to-scale model, we managed to get some help from Kitewa woodworking studio [1]. The following are some images of the building process:

Figure 5.5 Cutting of Materials

Figure 5.6 Assemblying the Wood

Figure 5.7 Flaten the Wood Piece

Figure 5.8 Making the Living Hinges

Figure 5.9 KAN.KA Base Construction is Done

5.3. Final Product - WIP

These are some images of how KAN.KA can be used in different forms and context:

Figure 5.10 KAN.KA Furniture - Front View

Figure 5.11 KAN.KA Furniture - Side View

Figure 5.12 KAN.KA Furniture - Seat Form

Figure 5.13 KAN.KA Furniture for Sleeping

Notes

1 http://kitewa.jp/

Figure 5.14 KAN.KA Furniture for Reading

Chapter 6
Conclusion

6.1. General Discussion

Emotion regulation has been an essential part of people's lives, which help them to function fully. However, there are always cases where emotions can be uncontrollable. This fact led to several studies in developing a technological intervention for emotion regulation. In order to design a good intervention, one needs to understand what emotions we are regulating, when we are applying the intervention and how to regulate those emotions.

In this context, Affective Haptic Furniture looks at the challenge of regulating emotional distractions in cognitive tasks that, at the same time, will not inhibit users from continuing their activities. To answer this challenge, we proposed the Affective Haptic Furniture concept, which explored the use of directional vibration patterns across-body to induce various emotions. Through a generate-select-verify method of study, we found the possibility of these vibration patterns to generate four basic emotions.

Using the findings from the first study, we also evaluated the concept of affective haptic furniture several times and in different contexts: reading a book and promoting positive aging. The goal of these assessments was to see if the vibration patterns can still induce a particular emotion and are useful in regulating negative emotions. In the reading task, we found that the patterns have a more significant impact on the arousal state of users' emotion. Some patterns were mentioned as calming and help users to remain focus on reading. In the positive aging demo day, we coupled the vibration patterns with nature sound and the results had been positive from both care staff group and elderly people group. Both groups enjoyed the furniture and stated that the system as helpful in reducing stress and gaining a sense of calmness.

Overall, we see potentials in Affective Haptic Furniture as a tool to regulate unwanted emotions in daily life. However, the limitations in the current design, along with the insights from user interviews, leave room for future improvement and development. In the next section, we will describe in details the current limitations and focus themes for future works.

6.2. Limitations and Future Works

From the results and the analysis of the 2-part study, we have managed to bring more insights to the next focus for future research and other application ideas of the vibration patterns. The main areas of interest for further development of this research are explained in detail below.

Physiological Aspect of Emotions for Smarter Furniture

In this study, we used Self Assessment Manikin to assess participants' emotional response. However, there are other physiological and bodily reactions to emotional stimuli such as heart rate, blood volume pulse, skin and body temperature, etc. Hence, for a further in-depth study, we hope to implement psychophysiological measurement to gain a comprehension assessment of the participants' emotional state.

In addition, the system could also be extended to allow automatic activation based on the user's physiological data or bodily reactions. For instance, if the external sensor senses a change in the user's emotion, the system could automatically render the right vibration pattern to regulate the undesirable emotion.

Extended Design Parameters and Multimodalities

The current design of vibration patterns focused on parameters such as movement and location on the body. For our next direction, we hope to explore more vibration parameters (e.g., a temporal delay, pulse patterns) in relation to the movement pattern. For example, within a single movement pattern, there could be different frequencies or number of pulses playing at differing times. This approach could create a dynamic of emotion within a moving vibration.

Another possibility to expand the emotional vocabulary of the haptic pattern is by adding other modality into the design. For instance, combining the sound of nature with the vibration pattern could potentially generate a different effect that is useful for emotion regulation strategy. During the positive aging demo day, we conducted a preliminary study of the multimodalities system. However, further investigation to find the most effective pairing of vibration and sound may be required.

Furniture and System Design, and Other Applications

Finally, the insights from the interview reported that actuator location has a significant influence on the perceived emotions. In the future study, we will design different forms of furniture (e.g., bed, sofa, car seat, etc.) to test this rising hypothesis and affirm the design parameters for affective furniture. An attachable and detachable design is also considered as it gives the flexibility to embed the vibration patterns onto any furniture. We will also implement the patterns for different emotion regulation applications. For instance, some relaxing patterns could potentially be used to help people who are struggling to fall asleep.

As for the system design, we noticed that while conducting the experiments, participants came in different body size and height. To render the same vibration pattern experience for all participants, we had to manually adjust the actuator locations. However, according to a recent study on seamless phantom sensation [1], it might be possible to use a Gaussian function to adjust the strength of each actuator and create an illusory of different actuator location. It means that we could automatically adjust the location of each actuator without having the need to physically move the actuator to fit participant's body size. We will explore this implementation as a future work.

Notes

1 http://hvr.postech.ac.kr/?q=international-demo

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Appendices

A. Haptic Pattern Code in MAX/MSP

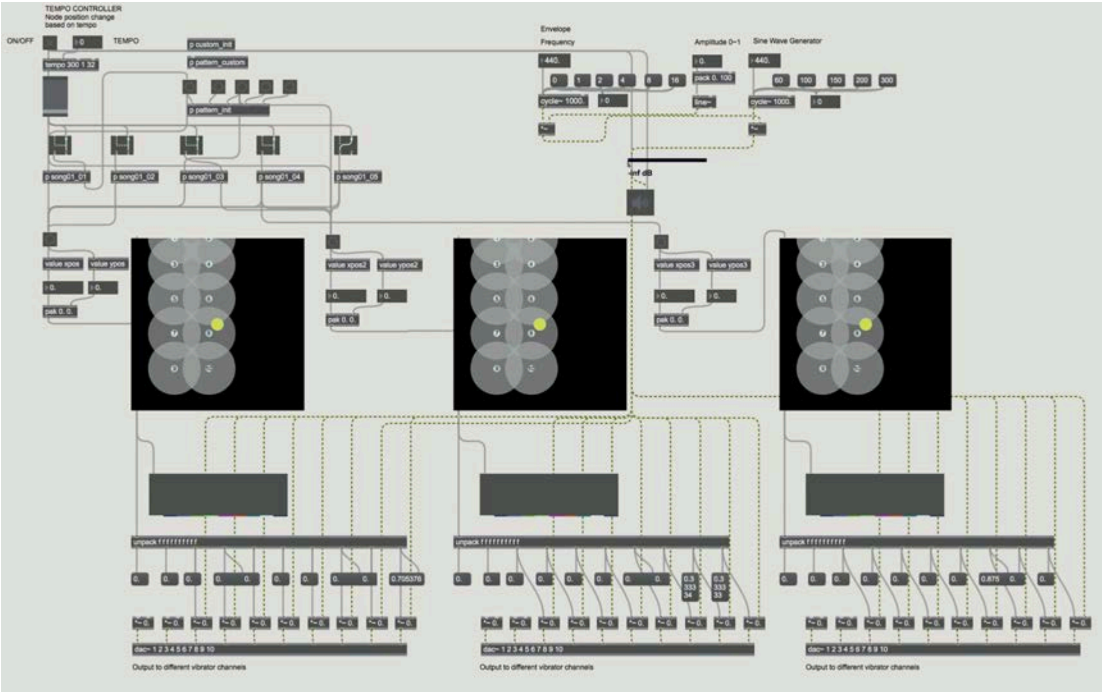

Figure A.1 Haptic Parameters Controller UI

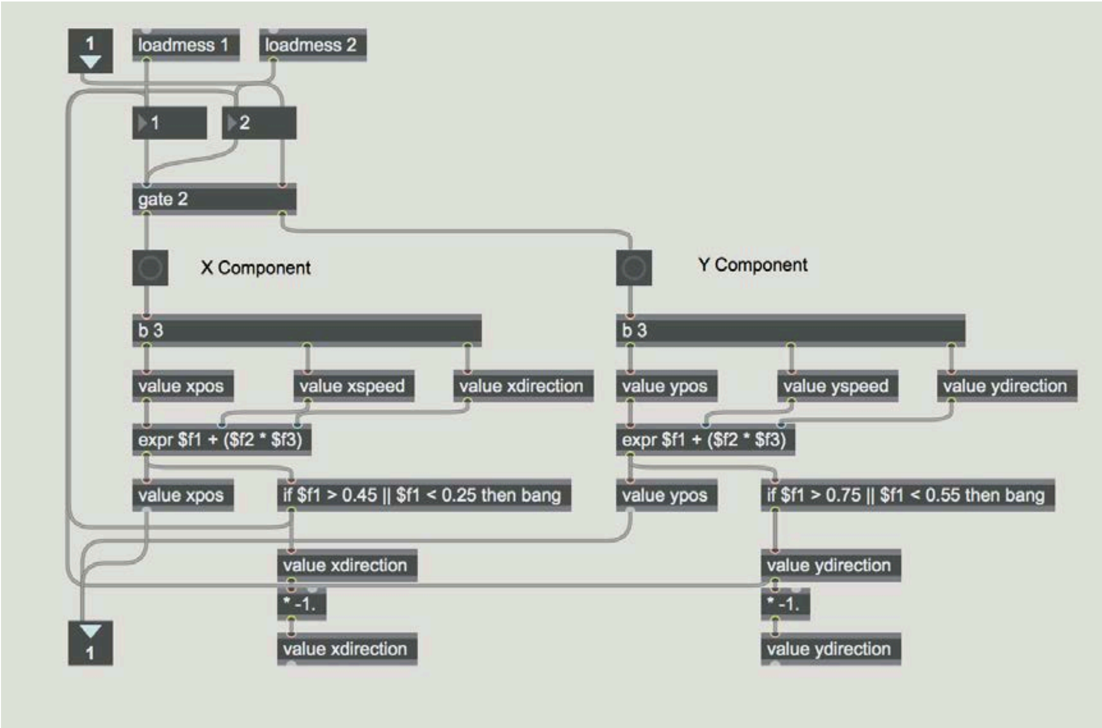

Figure A.2 A Sample of Moving Pattern Code

B. Study 1 Questionnaires

Song No: ______________________

Participant's Name: _____________

HAPTIC DESCRIPTION DESIGN SHEET

1) Please fill in the box with numbers from 1 to (up to) 8 that represent the sequence of vibration pattern that match the emotion that the song is eliciting in you.

2) Please describe the vibration pattern design as a sentence that represent the emotion that the song is eliciting in you.

3) Other comments. (If you feel like there's a specific movement that should represent the emotion please describe below.)

Figure B.1 Haptic Description Design Sheet

Song No: ________________ **Participant's Name:** __________________

HAPTIC RANKING SHEET
Please rank the vibration pattern from 1 to 5 based on its appropriateness to represent the emotion induced by the song. (1: the least appropriate, 5 : the most appropriate).

Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5

Figure B.2 Haptic Description Rating Sheet used in Select Group

Song No: ________________ **Participant's Name:** __________________

HAPTIC RANKING SHEET
Please rank the vibration pattern from 1 to 5 based on its appropriateness to represent the emotion induced by the song. (1: the least appropriate, 5 : the most appropriate).

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10

Figure B.3 Haptic Description Rating Sheet used in Verify Group