
Vibrotactile Stimulation for Wellbeing, Communication, and Creativity

Notes Towards a Research Strategy Involving Haplós, a Low-cost Wearable Vibrotactile Device

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1 Introduction

1.1 What is Haplós?

Haplós is a low-cost body awareness tool that applies programmable, vibrotactile patterns to the skin using small, vibrating motors (Fig. 1). It is inspired by research and design in clothing and human-computer interaction, in which clothing and wearable artifacts generate novel, embodied, somatic experiences [1]. Unlike many contemporary digital technologies for the body, Haplós was invented with the aim not of replacing or augmenting the human senses, but of enhancing our existing sensory abilities, particularly our ability to sense ourselves. Haplós was invented as part of a 4.1 million European Commission investment into the CogNovo PhD program (2013 -2017)¹ at Plymouth University, UK [2] in partnership with London-based design company Kin.² The inventor of Haplós (and author of this paper) was a Marie Curie Research Fellow³ at CogNovo and is an Assistant Professor of Multimedia Studies at the University of the Philippines.



Fig. 1. Current prototype of the Haplós system attached to a commercially available back support garment and worn by a user. While the motors are stimulating this user's back, they can be applied to any part of the body.

1.2 What does Haplós look like?

The heart of the *hardware and textile component* of Haplós is a set of brushless vibration motors on which male snap fasteners are affixed. These motors can be

¹ <https://www.cognovo.eu/>

² <http://www.fkin-design.com>

³ <https://ec.europa.eu/research/mariecurieactions/>

attached to female snap fasteners sewn onto a piece of ribbon (Fig. 2a), allowing for easy repositioning, unlike in most vibrotactile garments (Fig. 2b). The ribbon can then be attached to a wide variety of existing clothing and implements, and formed into any shape, making Haplós more flexible than most vibrotactile technologies. The motors are powered by a battery pack and controlled by a wirelessly-controlled microcontroller. Haplós can thus be controlled and reprogrammed over a local network or even the Internet.



Fig. 2. From left to right: a) Close-up of repositionable motors and the microcontroller system and battery pack; b) The motors attached to a commercial posture correction vest; c) The mobile interface for programming the motors.

The Haplós *software* is best described in terms of the graphical user interface (GUI) used to control the motors (Fig. 2c). Our prototype uses a step sequencer (akin to those used in music synthesizing tools) to compose tactile patterns. The GUI can be run on desktop and mobile devices. Tempo and motor intensity can be controlled from the GUI. Users can generate and send patterns on the fly, as well as save and play previously saved patterns. A single instance of the GUI can control multiple Haplós devices and mass broadcast the patterns.

1.3 How was Haplós created?

Haplós was designed by translating the principles of a body therapeutic and educational system – the Feldenkrais Method™ [3]–[6] – into a piece of wearable technology that was originally invented to enhance body awareness. The design of the technology was further motivated by research in neuroscience, kinesiology, and experimental psychology suggesting that vibrotactile stimulation can facilitate a range of different effects on an individual’s soft tissues and central nervous system. These effects include changes in muscle tone [7], suppler fascia [8], pain relief [9], improved motor skill [10]–[12], and relaxation [13].

1.4 How does Haplós enhance body awareness?

Haplós is theorized to increase body awareness by developing more detailed representations of the body in the somatosensory cortex through the systematic application of pleasant vibrotactile stimuli, using motors that are spaced just below

the two-point tactile discrimination threshold [14]. The work of Rosenkranz and Rothwell [15]–[17] suggests that vibrotactile stimulation can expand cortical representations of stimulated body surfaces. Building on and inspired by their work, Haplós applies carefully designed patterns of vibrotactile stimulation to the skin in such a way as to supply a subject with higher resolution information of an area of their body, with the aim of increasing the somatosensory cortical representation of that part of themselves. To do so, motors are first spaced on a user’s body just at the threshold of two-point tactile discrimination threshold. Once placed on the user’s skin, the motors play a sequence vibrotactile patterns via the mobile interface. The initial patterns are temporally and spatially simple, meaning that they are often rhythmically regular, repeating, and linear, in order to allow the user to anticipate where on their skin they might expect the vibrotactile stimuli to be applied. The patterns then become increasingly more complex, but are always repeated in order allow users to predict where the stimuli might be applied. Repetition is used as a teaching strategy. In this manner, complex vibrotactile stimuli applied to the subject become increasingly familiar. The ‘composition’ ends by decreasing in complexity until the initial, simpler patterns are played. Users who have experienced Haplós often report that the initial patterns feel clearer and more perceptible at the end than at the beginning of the composition. After taking off Haplós, users are asked to feel themselves in standing and walking and notice and report any changes in their perception of their body, which there often are. To the best of our knowledge, Haplós is the first wearable technology created with the intent of changing representations of the self-image using vibrotactile stimulation.

1.5 What’s next?

Building on the success of previous research on Haplós, we are currently seeking collaborators and funding opportunities both to continue research in current and to pursue future research on potential applications of Haplós for well-being, communication, and creativity. This concept note discusses eleven previous, current, and potential areas:

1. Body awareness
2. Food cravings
3. Touch-based therapies
4. Bodily creativity (the RE/ME project)
5. The Haplós Open Source Development Kit
6. Sensorimotor rehabilitation
7. Remote communication and presence
8. Addition and depression
9. Improved cognition: Attention, mindfulness, mood, and mental imagery
10. Virtual reality, augmented reality, and novel technology-mediated embodied experiences
11. New aesthetic forms, artistic possibilities, and entertainment modes

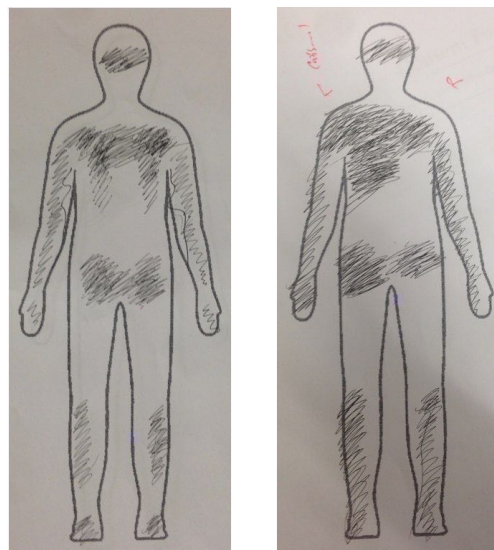
2 Previous Haplós research

2.1 Body awareness

Body awareness as facilitated by somatic and touch practices [1] is an important area of study because it can help with pain management [18]; reducing unhealthy cravings [19]; trauma recovery [20]–[22]; improving physical mobility and stability [23], [24]; improving self-perception [25], [26] and identity-formation [27]; influencing mental awareness [28]; sensory appreciation and pleasure [29]; and facilitating general wellbeing [30]. In a series of workshops, public outreach events, and controlled studies conducted in the UK, the Haplós team used 14 motors to play tactile patterns on areas of the back close to the spine and pelvis because of the crucial role these structures in the organization of everyday movement. We concentrated on the area between the scapulae, as this region is difficult both to see and touch, and tends to be poorly represented in the individual self-image. We borrowed techniques from the Feldenkrais Method to structure the experience and direct users' attention to the effects of wearing Haplós, such as unilaterally stimulating the body to create a differences in sensation across the sagittal plane (what is known as a 'one-sided lesson' in FM), experiencing movement pre- and post-stimulation, strategically integrating periods of rest (silence) in the tactile patterns, and using horizontal surfaces (such as a mat) as a "kinesthetic mirror" [31] to explore experiences of muscular tonus [32].

In these studies, Haplós created measurable effects on body awareness. Participants wearing Haplós reported a perceptible difference in how they experienced their body across the midsagittal plane when only one side of their backs were stimulated. Participants reported feeling more aware of the area that was stimulated; these reports were captured both in verbal reports and through visual representations they created of their perception of their awareness of their body. A tool for recording these experiences – an outline of the human form that participants could annotate – was used to record and share these perceptible differences in their embodied experience, shown in Fig. 3. As one research participant noted after experiencing Haplós:

[I could] feel more of myself ... I couldn't feel myself as much before. [32, p. 207]



3 Current Haplós research

3.1 Touch-based therapies

Given the success of our early studies into the use of Haplós for enhancing body awareness, the Haplós team aim to conduct larger studies using Haplós to investigate how to precisely customize the technology to enhance body awareness. Our pilot studies suggest that different people have different preferences to the strength, speed, and density of vibrotactile patterns; we wish to examine these factors in more detail, as well as other factors such as vibratory motor spacing and body placement, to reveal how best Haplós can be tuned to individual users and their needs.

Haplós could be applied to existing therapeutic approaches that already incorporate touch for technology-mediated therapeutic approaches with a tactile modality. Related work includes that of Chen et al. [36] who have reported using mini robots to seek and stimulate acupuncture points along the back, while Morrison et al. [37] have reported using vibrotactile stimuli to “meridian” points. A practice known as Havening [38] involves tapping parts of the body with a therapeutic intent; Haplós could conceivably be deployed as form of technology-mediated Havening. Commercial success of the wearable vibrotactile technology for other uses [39] indicates market readiness for new technology-based aids for well-being. A commercial technology that uses a vibrating implement to purportedly stimulate the vagus nerve in order to activate the sympathetic system and the ‘rest and digest response’ has recently been popularized in social media [40].

We are also interested in using neuroadaptive techniques such as evolutionary algorithms based on brain signals, such as captured by EEG devices, to compose and deliver specific vibrotactile patterns to the user. This was the basis of our award-winning proof-of-concept of a wearable neuroadaptive vibroacoustic therapeutic device at Hack the Brain 2017 in Amsterdam [41], shown in Fig. 5.



Fig. 5. Haplós used in Bisensorial, an award-winning proof-of-concept for a wearable neuroadaptive vibroacoustic therapy. Readings from a portable EEG sensor are used to create and evolve patterns of sound and vibration down the wearer's back to bring them to a desired mental state.

3.2 Bodily creativity (the RE/ME project)

RE/ME is an interactive installation based on Haplós and subsequently developed by Dr. Maranan along with speculative designer Agi Haines, composer Sean Clarke, computational neuroscientist Jack Fletcher, and computer scientist Frank Loesche. The team was formed out of the CogNovo program and was selected for the award out of approximately 25 other teams that were formed during a series of EU-funded events called Hack the Brain held in 2016 and 2017. RE/ME was one of five projects pitched at [Art, Science & Technology Collaborations in Europe](#), a symposium on how the arts can be a catalyst for innovations that seek to address today's challenges. RE/ME won the pitch and was chosen to be further developed at DART 17, a test laboratory in San Francisco, USA, with the help of a 10,000-euro grant. You can [check out the slides of the presentation and learn more about the project here](#).

The RE/ME team will be joining DART 17 in San Francisco in July and August, 2018. During their residency, they will create an interactive installation using a custom-made cradle and a version Haplós using 600 motors to create a full-body, immersive, tactile experience (Fig. 6). RE/ME will incorporate the use of music and sound to the carefully designed patterns of touch provided by Haplós. However, RE/ME can be further used to transform the user's experience of their body's size and shape in imaginative and novel ways. Using RE/ME, users can sculpt their perception of their body's shape and size.

Because of the costs associated with building installation, traveling to the US, and staying in San Francisco, we are seeking support to fund the four members of the RE/ME team, to supplement the 10,000-euro grant given by the European Commission.



Fig. 6. Proposed RE/ME installation to be built and tested at the DART17 technology lab in San Francisco.

3.3 Haplós Open Source Development Kit

We are looking to design, build, and distribute an open source development kit that will allow scientists, artists, designers, and healthcare providers to experiment with uses of Haplós for R&D in well-being, communication, and the arts. We believe that the sensory experiences of provided by Haplós have wide applicability to a variety of problem areas. We suspect that Haplós could potentially be used as a sleep aid, as a component of virtual and augmented reality experiences, and as an intervention for chronic pain, for instance. In order to produce the open source toolkit, we are looking to do the following:

- a) Redesign the physical form factor of Haplós so it can
 - a. be incorporated onto a wider variety of clothing and equipment
 - b. be applied to a wider variety and more parts of the body
 - c. be set to at a finer spatial resolution when appropriate
 - d. be more robust and adjustable to a wider variety of experimental situations
- b) Redesign the authoring tool for composing vibrotactile patterns to
 - a. allow for a wider variety of vibrotatile patterns
 - b. incorporate integrated audio composition as well
- c) Create an online platform that can act as a repository of Haplós-generated vibrotactile patterns and host discussion for a community of researchers, artists, and citizen-scientists working on vibrotactile stimuli-related work
- d) Design and manufacture a printed circuit board
- e) Package and distribute the development kits globally

4 Potential impact on social development

We see several future research trajectories involving Haplós, some of which have potential impact on social development and are supported by strategic research thrusts. In particular, research on the use of Haplós for sensorimotor rehabilitation and pain falls under, satisfies, and is in line with the following:

- Research priority for health research and development under biomedical equipment, rehabilitative medicine (2018 research priority) and persons with disabilities assistive device (2019 research priority), under the Philippine National Health Research System's 2017-2022 National Unified Health Research Agenda.⁴
- Republic Act 7277 (*Magna Carta for Disabled Persons*) on rehabilitation, self-development, and self-reliance of disabled persons⁵
- Rehabilitation and assistive technology under Action area #2 of the action framework of the Philippine Department of Health's Health and Wellness Program for Persons with Disabilities⁶
- Goal 3 (Good Health and Wellbeing) and Goal 17 (Partnerships) of the UN Sustainable Development Goals⁷

5 Future research on Haplós

5.1 Sensorimotor rehabilitation



We see a potential for Haplós to be used in sensorimotor rehabilitation, such as in post-stroke recovery. Vibration has been used to cancel muscular tremors in early studies and prototypes of devices for people with essential tremor [11], [12]. Vibrotactile stimulus has been used as an information cue for rehabilitating gait in hemiplegic subjects [42]–[44] as well as upper limb rehabilitation [45], [46], as well as providing haptic feedback in serious games for post-stroke rehabilitation [47]. One study found that the remote application of vibrotactile noise improves fingertip tactile sensation with potential to enhance dexterity for stroke survivors [48]. Hussain et al [49] designed and invested the use of a wearable robotic extra finger used by chronic stroke patients to compensate for the missing hand functions of the paretic limb. We suggest that Haplós' possible effect of intervening in the sensorimotor loop and creating greater tactile sensitivity can help with stroke rehabilitation. For instance, Haplós can be incorporated as part of mirror therapy by heightening the illusion through the same principle as the *rubber hand illusion* [50], [51], perhaps with the addition of

⁴ <http://www.pchrd.dost.gov.ph/index.php/downloads/category/4-nuhra>

⁵ <http://www.ncda.gov.ph/disability-laws/republic-acts/republic-act-7277/>

⁶ <https://www.doh.gov.ph/persons-with-disabilities>

⁷ <https://www.un.org/sustainabledevelopment/health/>

visual stimuli such as LEDs that light in synchrony and in the same location as the vibrotactile stimuli. In addition, Haplós could also be used as part of interactive intervention for improving the gait of people with neurological diseases, such as Parkinson's patients, who have been shown to respond well to a music therapy technique called rhythmic auditory stimulation [52].

5.2 Pain management



Moderate to severe chronic pain is relatively high in the Philippines, with 10.4% of the Filipino adult population and an annual incidence rate of 3.4% [53], even as the cost of treating chronic pain is a barrier to low-income Filipinos [53]. Previous experimental research has shown that pain intensity, tactile acuity and cortical reorganization are related [54]–[56], and that a tactile stimuli-based intervention that aims to increase tactile discrimination “would decrease pain and increase tactile acuity, but tactile stimulation alone would not” [54]. We theorize that Haplós can therefore assist with pain management since it aims precisely to increase tactile discrimination. In addition, a systematic review of interventions suggests that mirror therapy might be effective for treating complex regional pain syndrome [57]; if so, Haplós could be used to enhance mirror therapy as previously suggested in section 4.1.

In addition to the treatment of chronic pain and pain from sensorimotor deficits (such as phantom limb pain), we wish to investigate whether tactile-stimulation based treatments can be used to address other types of pain, such as cancer-related pain. In 2015, it was reported that 98,200 Filipinos are diagnosed annually with cancer, and that 75% of them die with intense pain [58]. Regulatory barriers and policy restrictions to opioid access to ease cancer-related pain exist in Southeast Asia but particularly in the Philippines [59]; loosening barriers is not a clear avenue towards addressing access to pain interventions, given that prevailing issues with opioid addiction in general [60], and substance addiction and “the war on drugs” in the Philippines in particular [61], [62].

Virtual reality has already shown to be beneficial to pain relief [63]–[65] and posited to be an alternative to opioid treatments [66], [67]. We theorize that Haplós can be part of low-cost, non-pharmacological multisensory stimuli-based interventions for alleviating pain that incorporates

an additional, under-explored sensory stimulus within existing paradigms that show promise for pain relief.

5.3 Addiction and depression



In the Elaborated Intrusion Theory of desire, substance addiction—a serious problem everywhere, and particularly in the Philippines [68], is an exaggerated form of craving. If Haplós can reduce the frequency of a craving, could it be turned into a personalized, sensory stimulation device that can be part of a larger strategy to address substance addiction? What if Haplós could be programmed to deliver ever-changing, novel, interesting sensory stimuli that can be used to cut the elaboration of intrusive thoughts, such as those associated with addiction and depression?

5.4 Improved cognition: Attention, mindfulness, mood, and mental imagery



Given the success of the experimental study on the use of Haplós for intrusive thoughts, we also wish to explore further uses of Haplós for attention, mindfulness, mood, and mental imagery in collaboration with Dr. Jackie Andrade and Dr. J on May of Plymouth University's School of Psychology

5.5 Remote communication and presence



Conveying presence and intimacy across the distance is important particularly because economic pressures have resulted in economic migrants and created distributed families who rely on electronic communication systems as their only means of contact for long periods of time. The lack of physical intimacy within this diasporic group is thought to be related to accompanying social and health problems [69]. Another area in which remote technologies for conveying somatic presence ultimately involves online communities, such as online communities of learners studying in open, distance, and e-learning (ODEL) environments [70]. In ODeL environments, the lack of physical presence of fellow students and instructors can have a negative impact on learner experience (REF). Tactile interactions have been explored for enhancing remote interpersonal interactions [71], some of which use vibrotactile stimuli [72], such as those delivered by Haplós, but few (such as [73]) consider whole body tactile experiences, and none have been successfully

commercialized and many have have been largely limited to experimental art installations or speculative designs. We are interested in investigating whether a remote somatic intimacy provided by the Haplós vibrotactile system in tandem with more conventional electronic text and video communication systems may alleviate social intimacy between remotely separated families as well as ODeL learners. In this project, the assigned research assistant will explore how to facilitate physical presence and intimacy remotely. The use of a low-cost vibrotactile-capable technology such as Haplós will be a suggested starting point for the research, but exploration of other avenues will be encouraged.

5.6 Virtual reality, augmented reality, and novel technology-mediated embodied experiences



We suggest that whole body vibrotactile technologies such as Haplós can play a central role in enriching virtual and augmented reality experiences. For instance, the rubber hand illusion can create radically new and compelling sensory experiences through the coordinated use of tactile stimulation and visual cues [50], [74], [75]. Haplós could potentially be used to create and sustain novel embodied experiences through the rubber hand illusion effect, as has been done in previous, deeply compelling experiments in which participants were led to believe that they inhabited a completely different kind of body [74].

5.7 New aesthetic forms, artistic possibilities, and entertainment modes



As sensory phenomena, vibrotactile stimuli and auditory stimuli are fundamentally similar in that they enter the field of awareness through mechanotransduction [76], the biological process of converting mechanical energy into electrical impulses in the nervous system, which are eventually experienced as tactile or auditory phenomena. Interestingly, sound can heighten the experience of tactile stimulation [77], and vice-versa [78]. This close correspondence between mechanical vibration and audible sound has motivated artistic and design practices that bring these two sensory modalities together. This has been exploited in commercial products such as the SubPac⁸ and the SpinalTAD⁹ which play audio directly onto a user's torso, and is particularly evidenced in the

⁸ <http://subpac.com/>

⁹ <http://www.tadsinc.com/products/spinaltad/>

body of work of Eric Gunther, who has coupled vibration with sound in a number of different pieces, including *Organ Organ* [79] and *Vibravive-VL12* [80]. Both works involve a user reclining or lying prone on a soft surface through which they experience a multimodal composition for sound and vibration. Donnarumma [81] has used vibration as effected through sound and whole-body vibration to create unusual physiological experiences in his artwork, *Nigredo*. Haplós capacity for transmitting vibrotactile information remotely, wirelessly, and in a distributed manner, to deliver precisely targeted tactile experiences, opens up new possibilities for the arts and entertainment.

6 Acknowledgments

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7 Bibliography

- [1] T. Hanna, *Somatics: reawakening the mind's control of movement, flexibility, and health*. Cambridge, MA: Da Capo Life Long, 1988.
- [2] D. S. Maranan, F. Loesche, and S. L. Denham, "CogNovo: Cognitive Innovation for Technological, Artistic, and Social Domains," in *Proceedings of the 21st International Symposium on Electronic Art*, Vancouver, Canada, 2015.
- [3] M. Feldenkrais, *Awareness through movement; health exercises for personal growth*, 1st ed. New York: Harper & Row, 1972.
- [4] M. Kimmel, C. Irran, and M. A. Luger, "Bodywork as systemic and inter-enactive competence: participatory process management in Feldenkrais® Method and Zen Shiatsu," *Front. Psychol.*, vol. 5, p. 1424, 2014.
- [5] J. Mattes, "Attentional Focus in Motor Learning, the Feldenkrais Method, and Mindful Movement," *Percept. Mot. Skills*, vol. 123, no. 1, pp. 258–276, Aug. 2016.
- [6] Y. Rywerant, *The Feldenkrais method: teaching by handling*. North Bergen, NJ: Basic Health Publications, in association with the K.S. Giniger Co., New York, N.Y., 2003.
- [7] H. S. Park and B. J. Martin, "Contribution of the tonic vibration reflex to muscle stress and muscle fatigue," *Scand. J. Work. Environ. Health*, vol. 19, no. 1, pp. 35–42, Feb. 1993.
- [8] P. Frenzel, R. Schleip, and A. Geyer, "Responsiveness of the plantar fascia to vibration and/or stretch," *J. Bodyw. Mov. Ther.*, vol. 19, no. 4, p. 670, Oct. 2015.

- [9] K. Inui, T. Tsuji, and R. Kakigi, "Temporal Analysis of Cortical Mechanisms for Pain Relief by Tactile Stimuli in Humans," *Cereb. Cortex*, vol. 16, no. 3, pp. 355–365, Mar. 2006.
- [10] H.-O. Karnath, J. Konczak, and J. Dichgans, "Effect of prolonged neck muscle vibration on lateral head tilt in severe spasmodic torticollis," *J. Neurol. Neurosurg. Psychiatry*, vol. 69, no. 5, pp. 658–660, Nov. 2000.
- [11] K. C. Curay, "Woman with Parkinson's Can Write Again Using Donated Invention," *Mobile Magazine*, 23-Dec-2016. .
- [12] A. Pathak, J. A. Redmond, M. Allen, and K. L. Chou, "A noninvasive handheld assistive device to accommodate essential tremor: A pilot study," *Mov. Disord.*, vol. 29, no. 6, pp. 838–842, May 2014.
- [13] E. Gunther, G. Davenport, and S. O'Modhrain, "Cutaneous Grooves: Composing for the Sense of Touch," in *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2002.
- [14] K. O. Johnson and J. R. Phillips, "Tactile spatial resolution. I. Two-point discrimination, gap detection, grating resolution, and letter recognition," *J. Neurophysiol.*, vol. 46, no. 6, pp. 1177–1192, Dec. 1981.
- [15] K. Rosenkranz and J. C. Rothwell, "The effect of sensory input and attention on the sensorimotor organization of the hand area of the human motor cortex," *J. Physiol.*, vol. 561, no. 1, pp. 307–320, Nov. 2004.
- [16] K. Rosenkranz and J. C. Rothwell, "Spatial attention affects sensorimotor reorganisation in human motor cortex," *Exp. Brain Res.*, vol. 170, no. 1, pp. 97–108, Mar. 2006.
- [17] K. Rosenkranz and J. C. Rothwell, "Differences between the effects of three plasticity inducing protocols on the organization of the human motor cortex," *Eur. J. Neurosci.*, vol. 23, no. 3, pp. 822–829, 2006.
- [18] E. Eriksson, "Body awareness therapy: A new strategy for relief of symptoms in irritable bowel syndrome patients," *World J. Gastroenterol.*, vol. 13, no. 23, p. 3206, 2007.
- [19] D. K. Kavanagh, J. May, and J. Andrade, "Sensory imagery in craving: From cognitive psychology to new treatments for addiction.," 2012.
- [20] T. S. Madsen, J. Carlsson, M. Nordbrandt, and J. A. Jensen, "Refugee experiences of individual basic body awareness therapy and the level of transference into daily life. An interview study," *J. Bodyw. Mov. Ther.*, vol. 20, no. 2, pp. 243–251, Apr. 2016.
- [21] C. Price, "Body-oriented therapy in recovery from child sexual abuse: an efficacy study," *Altern. Ther. Health Med.*, vol. 11, no. 5, pp. 46–57, 2005.
- [22] B. A. Van Der Kolk, "Clinical Implications of Neuroscience Research in PTSD," *Ann. N. Y. Acad. Sci.*, vol. 1071, no. 1, pp. 277–293, Jul. 2006.
- [23] M. A. Lindvall, A. Anderzén Carlsson, and A. Forsberg, "Basic Body Awareness Therapy for patients with stroke: Experiences among participating patients and physiotherapists," *J. Bodyw. Mov. Ther.*, vol. 20, no. 1, pp. 83–89, Jan. 2016.
- [24] C. Sjö Dahl, G.-B. Jarnlo, and B. M. Persson, "Gait improvement in unilateral transfemoral amputees by a combined psychological and physiotherapeutic treatment," *J. Rehabil. Med.*, vol. 33, no. 3, pp. 114–118, 2001.
- [25] D. Catalan-Matamoros, L. Helvik-Skjaerven, M. T. Labajos-Manzanares, A. Martínez-de-Salazar-Arboleas, and E. Sánchez-Guerrero, "A pilot study on the effect of Basic Body Awareness Therapy in patients with eating disorders: a randomized controlled trial," *Clin. Rehabil.*, vol. 25, no. 7, pp. 617–626, Jul. 2011.

- [26] L. D. Miller, "The Ultimate Rx: Cutting Through the Delusion of Self-cherishing," in *Handbook of Mindfulness*, R. E. Purser, D. Forbes, and A. Burke, Eds. Springer International Publishing, 2016, pp. 337–352.
- [27] A. L. Gyllensten, L. Skär, M. Miller, and G. Gard, "Embodied identity – A deeper understanding of body awareness," *Physiother. Theory Pract.*, vol. 26, no. 7, pp. 439–446, 2010.
- [28] A. L. Gyllensten, "Outcome of Basic Body Awareness Therapy. A Randomized Controlled Study of Patients in Psychiatric Outpatient Care," *Adv. Physiother.*, vol. 5, no. 4, pp. 179–190, 2003.
- [29] R. Shusterman, *Body Consciousness: A Philosophy of Mindfulness and Somaesthetics*. Cambridge ; New York: Cambridge University Press, 2008.
- [30] O. Brani, K. Hefferon, T. Lomas, I. Ivtzan, and J. Painter, "The impact of body awareness on subjective wellbeing: The role of mindfulness," *Int. J. Body Psychother.*, vol. 13, no. 1, pp. 94–107, 2014.
- [31] F. Wildman, *The Busy Person's Guide to Easier Movement: 50 Ways to Achieve a Healthy, Happy, Pain-Free and Intelligent Body*, 3rd Revised edition edition. Berkeley, Calif.: Feldenkrais Movement Institute, 2006.
- [32] D. S. Maranan, "Haplós: Towards Technologies for and Applications of Somaesthetics," Ph.D. Thesis, Plymouth University, UK, 2017.
- [33] J. Andrade, J. May, and D. Kavanagh, "Conscious and unconscious processes in human desire," 2008.
- [34] D. J. Kavanagh, J. Andrade, and J. May, "Imaginary Relish and Exquisite Torture: The Elaborated Intrusion Theory of Desire.," *Psychol. Rev.*, vol. 112, no. 2, pp. 446–467, 2005.
- [35] J. Andrade, S. Pears, J. May, and D. J. Kavanagh, "Use of a clay modeling task to reduce chocolate craving," *Appetite*, vol. 58, no. 3, pp. 955–963, Jun. 2012.
- [36] H. Chen, X. Wu, W. Feng, T. Xu, and Y. He, "Design and path planning of Massagebot: One massaging robot climbing along the acupuncture points," in *2016 IEEE International Conference on Information and Automation (ICIA)*, 2016, pp. 969–973.
- [37] A. Morrison, C. Manresa-Yee, and H. Knoche, "Vibrotactile and vibroacoustic interventions into health and well-being," *Univers. Access Inf. Soc.*, pp. 1–16, Jan. 2017.
- [38] G. Thandi, "Impact of a Single-Session of Havening," *Health Sci. J.*, 2015.
- [39] Q. Wang, "Designing Posture Monitoring Garments to Support Rehabilitation," 2016, pp. 709–712.
- [40] S. Chmelik, "Vagal toning," *New Medicine Group*, 24-Nov-2017. .
- [41] D. S. Maranan, A. Haines, J. Fletcher, and S. Clarke, "Bisensorial: A brain-computer interface hack using tactile and auditory stimuli," presented at the Cognition Institute Conference 2016, Plymouth University, UK, 07-Jul-2016.
- [42] D. L. Jaffe, D. A. Brown, C. D. Pierson-Carey, E. L. Buckley, and H. L. Lew, "Stepping over obstacles to improve walking in individuals with poststroke hemiplegia," *J. Rehabil. Res. Dev.*, vol. 41, no. 3, p. 283, 2004.
- [43] M. R. Afzal, M.-K. Oh, C.-H. Lee, Y. S. Park, and J. Yoon, "A Portable Gait Asymmetry Rehabilitation System for Individuals with Stroke Using a Vibrotactile Feedback," *BioMed Res. Int.*, vol. 2015, p. 375638, 2015.
- [44] C. Z.-H. Ma, Y.-P. Zheng, and W. C.-C. Lee, "Changes in gait and plantar foot loading upon using vibrotactile wearable biofeedback system in patients with stroke," *Top. Stroke Rehabil.*, vol. 25, no. 1, pp. 20–27, 2018.

- [45] P. Kapur, S. Premakumar, S. A. Jax, L. J. Buxbaum, A. M. Dawson, and K. J. Kuchenbecker, "Vibrotactile feedback system for intuitive upper-limb rehabilitation," in *EuroHaptics conference, 2009 and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems. World Haptics 2009. Third Joint, 2009*, pp. 621–622.
- [46] A. Karime, H. Al-Osman, W. Gueaieb, and A. El Saddik, "E-Glove: An electronic glove with vibro-tactile feedback for wrist rehabilitation of post-stroke patients," in *Multimedia and Expo (ICME), 2011 IEEE International Conference on, 2011*, pp. 1–6.
- [47] A. Alamri, H.-N. Kim, J. Cha, and A. El Saddik, "Serious Games for Rehabilitation of stroke patients with Vibrotactile feedback.," *Int. J. Comput. Sci. Sport Int. Assoc. Comput. Sci. Sport*, vol. 9, no. 2, 2010.
- [48] L. R. Enders, P. Hur, M. J. Johnson, and N. J. Seo, "Remote vibrotactile noise improves light touch sensation in stroke survivors' fingertips via stochastic resonance," *J. Neuroengineering Rehabil.*, vol. 10, no. 1, p. 105, 2013.
- [49] I. Hussain *et al.*, "Using the robotic sixth finger and vibrotactile feedback for grasp compensation in chronic stroke patients," in *Rehabilitation Robotics (ICORR), 2015 IEEE International Conference on, 2015*, pp. 67–72.
- [50] N. Barnsley, J. H. McAuley, R. Mohan, A. Dey, P. Thomas, and G. L. Moseley, "The rubber hand illusion increases histamine reactivity in the real arm," *Curr. Biol.*, vol. 21, no. 23, pp. R945–R946, Dec. 2011.
- [51] M. Botvinick and J. Cohen, "Rubber hands 'feel' touch that eyes see," *Nature*, vol. 391, no. 6669, pp. 756–756, Feb. 1998.
- [52] M. J. Hove, K. Suzuki, H. Uchitomi, S. Orimo, and Y. Miyake, "Interactive Rhythmic Auditory Stimulation Reinstates Natural 1/f Timing in Gait of Parkinson's Patients," *PLOS ONE*, vol. 7, no. 3, p. e32600, Mar. 2012.
- [53] M. D. Lu and M. D. Javier, "Prevalence and treatment of chronic pain in the Philippines," *Philipp. J. Intern. Med.*, vol. 49, no. 2, pp. 61–69, 2012.
- [54] G. L. Moseley, N. M. Zalucki, and K. Wiech, "Tactile discrimination, but not tactile stimulation alone, reduces chronic limb pain," *Pain*, vol. 137, no. 3, pp. 600–608, Jul. 2008.
- [55] G. L. Moseley, "I can't find it! Distorted body image and tactile dysfunction in patients with chronic back pain," *Pain*, vol. 140, no. 1, pp. 239–243, 2008.
- [56] G. L. Moseley, A. Gallace, and C. Spence, "Bodily illusions in health and disease: physiological and clinical perspectives and the concept of a cortical 'body matrix,'" *Neurosci. Biobehav. Rev.*, vol. 36, no. 1, pp. 34–46, 2012.
- [57] N. E. O'Connell, B. M. Wand, J. McAuley, L. Marston, and G. L. Moseley, "Interventions for treating pain and disability in adults with complex regional pain syndrome," *Cochrane Database Syst. Rev.*, vol. 11, 2011.
- [58] J. R. Uy, "'75% of Filipino cancer victims die with excruciating pain,'" *The Philippine Daily Inquirer (Online edition)*, 26-Feb-2015.
- [59] D. H. Q. Think *et al.*, "Analgesic Prescription Patterns and Pain Outcomes in Southeast Asia: Findings From the Analgesic Treatment of Cancer Pain in Southeast Asia Study," *J. Glob. Oncol.*, vol. 4, pp. 1–10, 2017.
- [60] G. Peltz and T. C. Südhof, "The Neurobiology of Opioid Addiction and the Potential for Prevention Strategies," *Jama*, vol. 319, no. 20, pp. 2071–2072, 2018.
- [61] S. Cousins, "Five thousand dead and counting: the Philippines' bloody war on drugs," *BMJ*, vol. 355, p. i6177, Nov. 2016.

- [62] Dangerous Drugs Board, "Facts on Drugs," *Republic of the Philippines Office of the President*, 23-May-2013. [Online]. Available: <https://www.ddb.gov.ph/research-statistics/46-sidebar/58-facts-on-drugs>. [Accessed: 04-Jun-2018].
- [63] V. C. Tashjian *et al.*, "Virtual Reality for Management of Pain in Hospitalized Patients: Results of a Controlled Trial," *JMIR Ment. Health*, vol. 4, no. 1, p. e9, 2017.
- [64] H. G. Hoffman *et al.*, "Modulation of thermal pain-related brain activity with virtual reality: evidence from fMRI," *Neuroreport*, vol. 15, no. 8, pp. 1245–1248, Jun. 2004.
- [65] A. Li, Z. Montaña, V. J. Chen, and J. I. Gold, "Virtual reality and pain management: current trends and future directions," *Pain Manag.*, vol. 1, no. 2, pp. 147–157, Mar. 2011.
- [66] T. Jones, T. Moore, and J. Choo, "The Impact of Virtual Reality on Chronic Pain," *PloS One*, vol. 11, no. 12, p. e0167523, 2016.
- [67] C. T. Loguidice, "Virtual Reality for Pain Management: A Weapon Against the Opioid Epidemic?," *Clinical Pain Advisor*, 05-Sep-2017. [Online]. Available: <https://www.clinicalpainadvisor.com/painweek-2017/chronic-pain-management-with-virtual-reality/article/684461/>. [Accessed: 04-Jun-2018].
- [68] F. Godlee and R. Hurley, "The war on drugs has failed: doctors should lead calls for drug policy reform," *BMJ*, p. i6067, Nov. 2016.
- [69] E. R. Gregorio, "The Filipino seafarers' lived experiences aboard international shipping vessels: A basis for health promotion intervention," *Acta Med. Philipp.*, vol. 46, no. 3, pp. 69–74, 2012.
- [70] P. B. Arinto, "A framework for developing competencies in open and distance e-learning," *Int. Rev. Res. Open Distrib. Learn.*, vol. 14, no. 1, pp. 167–185, Feb. 2013.
- [71] M. Azh, S. Zhao, and S. Subramanian, "Investigating expressive tactile interaction design in artistic graphical representations," *ACM Trans. Comput.-Hum. Interact. TOCHI*, vol. 23, no. 5, p. 32, 2016.
- [72] H. A. Samani, R. Parsani, L. T. Rodriguez, E. Saadatian, K. H. Dissanayake, and A. D. Cheok, "Kissenger: Design of a Kiss Transmission Device," in *Proceedings of the Designing Interactive Systems Conference*, New York, NY, USA, 2012, pp. 48–57.
- [73] J. K. S. Teh, A. D. Cheok, R. L. Peiris, Y. Choi, V. Thuong, and S. Lai, "Huggy Pajama: a mobile parent and child hugging communication system," in *Proceedings of the 7th international conference on Interaction design and children*, 2008, pp. 250–257.
- [74] B. van der Hoort, A. Guterstam, and H. H. Ehrsson, "Being Barbie: The Size of One's Own Body Determines the Perceived Size of the World," *PLoS ONE*, vol. 6, no. 5, p. e20195, May 2011.
- [75] Y. Yuan and A. Steed, "Is the rubber hand illusion induced by immersive virtual reality?," in *2010 IEEE Virtual Reality Conference (VR)*, 2010, pp. 95–102.
- [76] T. Suslak, J. A. McKay-Fletcher, D. Armstrong, A. Jarman, and G. Bewick, "Modelling mechanotransduction in primary sensory endings," presented at the Neuroinformatics 2013 6th INCF Congress, 2013.
- [77] S. Merchel and M. E. Altinsoy, "Vibration in Music Perception," in *Audio Engineering Society Convention 134*, 2013.

- [78] J. Huang, D. Gamble, K. Sarnlertsophon, X. Wang, and S. Hsiao, "Feeling Music: Integration of Auditory and Tactile Inputs in Musical Meter Perception," *Adv. Exp. Med. Biol.*, vol. 787, pp. 453–461, 2013.
- [79] E. Gunther, *Organ Organ*. 2007.
- [80] E. Gunther, *Vibravibe VL-12*. 2005.
- [81] M. Donnarumma, "Configuring Corporeality: Performing Bodies, Vibrations and New Musical Instruments," Goldsmiths, University of London, London, 2016.