Embodying Neuroplastic Change

Danielle Wilde

2013-2014 Sidney Myer Creative Fellow

Visiting Research Fellow, RMIT University

Australia

d@daniellewilde.com

CHI'13, April 27 – May 2, 2013, Paris, France.

Abstract

Groundbreaking neuroplasticity research demonstrates how interactive technologies can be used to leverage and increase our brain's capacity to learn. Importantly, unless specific physical pathologies are being addressed, this research remains screen-based, overlooking the rich multi-modal capacities of the human body. Embodied interaction affords multi-sensory experiences and heightened engagement. It allows for a broad palette of activities, as well as powerful leverage of the indelible intertwining of body and brain. This paper argues that embodied interaction, in particular poetic-kinaesthetic engagement in artistic activities, may powerfully compliment existing techniques for stimulating neuroplastic change.

Author Keywords

Embodied engagement; poetics; neuroplasticity; poetic-kinaesthetics; health; learning; abilitation; magical thinking; design innovation; design futures

ACM Classification Keywords

H.5.m. Information interfaces and presentation (Eg., HCI): Miscellaneous.
J.3. Life and Medical Sciences: Health.
J.4. Social and Behavioral Sciences: Psychology
J.5. Arts and Humanities: Arts, Fine and Performing

Introduction

Humans are born moving, and our bodies remain key to our engagement with the world throughout our lives [42]. Activities that focus on embodied engagement hold people's interest. The enriched experience of multi-modal stimulus is familiar, and stimulates the brain in complex and effective ways [13, 38, 40].

Many people, in particular in the HCI (Human Computer Interaction) research communities, are familiar with embodied interactive experiences (see [1] for examples). Such activities, wide-ranging in their focus and scope, are often novel and compelling though may not hold a participant's attention over time. They may engage intellectually but not imaginatively, on a kinaesthetic level; or kinaesthetically but not cognitively in sufficiently consistent ways to maintain engagement. So while engagement is enriched, and at first compelling, it may not be suitable for the longer-term commitment required for neuroplastic change.

Neuroplasticity is our brain's ability to plastically change at the neuronal level, to remap, or map new neural pathways. It is characterised by the mnemonic: "Neurons that fire together, wire together". Learning links neurons in new ways, and each time two neurons link a chemical change occurs that makes this link more likely. The key to stimulating neuroplastic change is repetition: repeated firing of neurons eventually results in the 're-wiring' of neural preferences and behaviors in favor of the more often repeated (and strengthened) pathway/s [14, 22].

Dramatic improvements in cognitive function have been reported when using interactive technologies to prompt neuroplastic change for a range of deficits. For example, to assist children with learning difficulties [4]; people with autism, with age, illness or accident-related cognitive decline [33, 34]; and people with physical pathologies, including vestibular disorder, and the sight-impaired or blind [5, 6]. Importantly, unless specific physical pathologies are being addressed, this research typically remains screen-based: engaged with through keyboard, mouse and monitor ([14] for an overview). These screen-based activities may be effective, however they overlook the multi-modal capacities of the body and how enriched environments stimulate brain development [13, 38, 40].

Embodied interaction affords enriched, multi-sensory experiences and heightened engagement [48]. Such engagement may, in certain cases, be more effective than the screen-based neuroplasticity exercises currently garnering dramatic results. Enriched embodied engagement would allow for a more inclusive palette of activities, as well as powerful leverage of the indelible intertwining of body and brain [20]. Yet if embodied interactive activities are to effectively stimulate neuroplastic change they must be sufficiently engaging to be repeated over a longer period.

In this paper I discuss how poetic-kinaesthetic engagement in artistic activities - where the body is engaged through the imagination, the imagination through the body, and cognitive and kinaesthetic load are tightly coupled [48] – may be ideally suited to affecting neuroplastic change. I detail three case studies that demonstrate how poetic-kinaesthetics have been shown to heighten attention, prolong engagement, and suggest surprising outcomes in learning, health, and design futures. The projects and related research collectively point to value in

understanding the neural impact of poetic-kinaesthetic activities, and an investigation of how this impact might be effectively leveraged to address or mitigate physical and, potentially, motorically-unrelated cognitive challenges. Engagement (or lack of) is acknowledged to be a key factor in the effectiveness of health, learning and abilitation strategies. I posit herein that poetic-kinaesthetics may transform such outcomes, not only by enhancing engagement, but by effectively supporting and stimulating neuroplastic change.

Related Work

Bach-y-Rita, notably, used physical computing to affect neuroplastic change to and through the body with remarkable success [5, 6]. Yet his concerns remained focused on the pathologies being addressed. His intention was not to imaginatively engage participants, but to provide an effective functional framework through which to stimulate the desired change. In contrast, V.S. Ramachandran famously engages patients' imagination and perception in their embodied experience, to address issues with phantom limbs (using mirrors rather than digital technologies) [37]. By leveraging the power of the imagination and magical thinking he is able to achieve remarkable transformations in relation to this little understood phenomenon. Poetic-kinaesthetic activities fall somewhere between these two approaches, bringing poetic, or imaginative embodied engagement to the fore (aka Ramachandran's approach), whilst leveraging the affordances of new and emerging technologies and technological thinking.

Numerous examples of poetically engaged technological experiences can be found at [1]. Embodied interaction enriches experience by engaging the multi-modal capacities of the body. Though the neural impact of such imaginatively engaged embodied interaction is yet to be investigated in depth, the heightened qualities afforded by such engagement is well noted (Ibid.), and Gao et. al. report short-term cognitive benefits from casual exergaming [18].

Cognitive science provides useful discussions around artistic engagement, the body and neuroscience. Preminger, for example, posits that engagement in artistic activities can be a means for long-term neuro-cognitive change [35]. Carney et al demonstrate that body posture and positioning impacts neurochemistry in ways that can lead to transformative outcomes [9]. From these examples, we might deduce that beginning with the body and/or the imagination when developing technological systems for embodied interaction may afford the development of activities that result in neuroplastic change. The approach outlined in this paper argues how and why this may occur.

Poetic-Kinaesthetics

Poetic-kinaesthetic engagement interweaves an embodied enquiry with an imaginative enquiry, leveraging the affordances of a direct pairing of technologies, or technological thinking, with the body [48]. Intertwining the body and the imagination through the use of technological systems seems to open up exciting possibilities for participants in particular when cognitive and kinaesthetic load are tightly coupled [48]. During poetic-kinaesthetic activities participants report feeling things they have not felt before, discovering new and exciting capacities in their bodies, and tapping into imaginative stores that previously remained inaccessible [48]. Some participants report lasting shifts in the way that they

Figure.1 First-time *hipDisk*-ers

think about key aspects of their lives, years after undertaking the activity, attributing these changes to the poetic-kinaesthetic experience [48]. Added to these encouraging results, people who typically hold back to observe often jump in to play, engaging willingly; and vast numbers of participants wish to discuss their experience immediately after, and to know when they might next engage [48]. Such outcomes have been consistent across a range of poetic-kinaesthetic activities. They resonate with the kind of residual "spin off of movement" commonly associated with activities such as running [42], though do not require the same level of skill or commitment, so are available across age groups and abilities and can be enjoyed on immediate encounter. Interestingly, these "residual spin off" feelings are also demonstrated by observers of poetic-kinaesthetics [48]. They indicate heightened qualities of attention and, in the case of observers, activation of mirror neurons – a direct and active link between the motor and sensory systems.

A basic aim of poetic-kinaesthetics is to make the body "unfamiliar," to increase the difficulty and length of perception and thereby "defamiliarise" the body [43]. A fundamental strategy in artistic expression [11], defamiliarisation is centered on the idea that the act of experiencing something occurs in the moment of perception and the further you confuse or otherwise prolong the moment of arriving at an understanding, the deeper or more detailed that understanding will be. Sheets-Johnstone's notion of "making strange" defamiliarises by bringing focus to and through the moving body using the power of embodied interaction [41]. Defamiliarisation heightens attention and extends engagement. The case studies below provide examples.

Embodying learning

hipDisk is a mechanical extension that requires gestural extension to give the body musical capabilities [46, 49]. Two horizontal disks emerge from the torso, one above the waist, one below (fig. 1). Each movement of the wearer that causes these disks to touch results in a tinny, electronically-generated tone that bursts forth from speakers mounted on the lower disk. By moving their bodies, *hipDisk*-ers can play simple melodies one note at a time. To play rhythmically or sonically more complex music, players must band together in socially engaged, embodied musical play. The sound motivates and gives meaning to *hipDisk*-ers' actions. The result is clumsy, yet engaging [49].

hipDisk frames the body so unusually that the attention of wearers and observers cycles continually between the actions and gestures of the body and the effects of physical engagement as expressed sonically. The interface provides startlingly satisfying musical feedback for extremely simple movements, yet achieving complex musical results, or any degree of mastery of the device, is not straightforward. The varied entry points afforded by the interface [46] afford a broad range of strategies for learning. Such openness brings to light individual learning preferences, as people instinctively look for the most comfortable way to learn how *hipDisk* behaves: through visual supports; physically: proprioceptively or kinaesthetically; with tactile or vocal support from others; through sound; or observation. Some participants even use spatial orientation, though hipDisk is self-contained and centered on the body, ensuring that no matter which direction the wearer faces the device's behavior is consistent [46].

Figure.2 *Light Arrays*

hipDisk affords heightened scrutiny of the relationship between gesture and output. Such heightened attention is typical of poetic-kinaesthetics, and may be useful for achieving long-term neuroplastic change, for which paying close attention is considered integral [30].

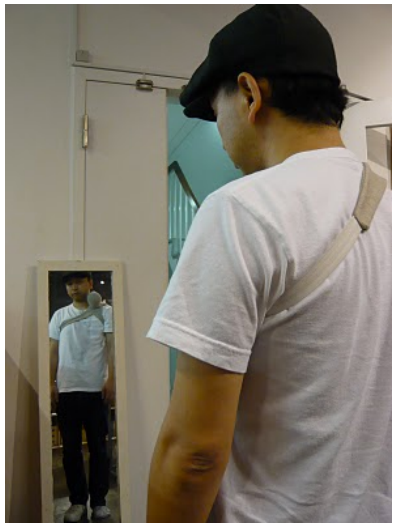
Embodying health

A major challenge in health and abilitation is patient engagement. Studies have shown that time spent in therapeutic activities is low and levels of engagement poor despite evidence that intensive rehabilitation speeds recovery [16]. It is recognized that performance goals that are meaningful for a patient are beneficial [54], and that enhancing patient engagement in self-managed care would be welcome [27]. Poetic-kinaesthetics may be well suited for this task [47], not least because of their ability to engage. They provide free-form expressive spaces that encourage different qualities of attention: on the task at hand, the actions and gestures of the body, as well as on the results of those actions as presented through the technology.

The Light Arrays is a series of poetic-kinaesthetics that extend the body with light (Fig.2). They include the *laserSpine*, which horizontally (passively) extrudes the spine with lasers, to magnify movement; inertialEDs, individually addressable arrays of LEDs that afford movement-play through time and space; and the in-visible skirt, a belt of laser-modules that suggest an A-line skirt, which can move and sway in response to the movement of a mobile, wearable controller [50] Light-based body extensions, such as the Light Arrays, are well suited to inspire people to engage their bodies through personally meaningful imaginative tasks, relevant to physiotherapeutic needs, or for other targeted health outcomes [48, 50].

By focusing on the results of actions, rather than the actions themselves, participants are able to enhance their ability to learn physical skills [23]. Bringing focus back to the body enhances self-awareness. Increasing physical dexterity and range, thus, may impact positively on a person's ability and ease communicating [17]. By exploring and testing the possibilities for action in their body [48], they dynamically shift their body schemas, enhancing their ability to communicate as they create and reflect on new and emerging modes and patterns of bodily experience.

Perception is a skilled activity [45] that leads to an awareness of affordances [21]. Poetic-kinaesthetic engagement may encourage those with low- or unconventionally-functioning bodies to use the neglected parts of their body willingly, inspired by the expressive potential of the light extensions. They may thereby allay further muscular degeneration and achieve greater physical control, as well as neuroplastic change, such as with Constraint Induced Movement Therapy (CI) [44]. Artist and ischemic stroke sufferer Sandra Hewitt-Parsons speaks of the advantages of tactile media aids to simulate the sensory system and improve visual-spatial awareness [25]. Highly positive results have been seen when similar techniques have been used by elite athletes to improve precision [24], when children and adults with cerebral palsy have undertaken intense dance training [20], and when children in neuro-medical and oncology wards have engaged in what Lisa Dowler describes as "shared dancing" [15]. Poetic-kinaesthetics provide an alternative to sports, dance and CI Therapy, whereby participants can engage expressively through their bodies in a multitude of personalisable (and therefore idiosyncratically engaging) ways.



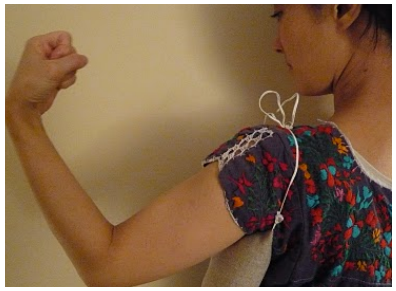


Figure.3 *OWL bodyProps*

Embodying design futures

The OWL project takes a different approach to poetic-kinaesthetic engagement, leveraging technological thinking rather than actual technologies to assist people to engage in embodied magical thinking, and thereby conceive of technologies that do-not-yet-exist. Rather than providing an open technology system that extends the body to provoke and support physically engaged creative expression and self-knowledge, the project engages participants in the embodied co-creation and collaborative imagining of radical new, what Arthur C. Clarke describes as "sufficiently advanced technologies", "indistinguishable from magic" [10].

The OWL project has two distinct phases. Phase one consists of open and speculative (technology-free) body-devices that have been designed without a pre-defined function and are tested or 'probed' through physically engaged interviews to ascertain imagined functionality (Fig.3) [51, 52]. The devices and interview process are designed to take test subjects through an emergent embodied thinking process, to assist them in articulating previously unimagined, and unmitigated body-technology desires. Phase two consists of collective making workshops – OWL circles – similar in form and construct to sewing circles, yet highly structured to support specific types of exploratory outcomes. Circle participants are guided through a series of estrangement switches [2] that result in personal exploratory body-devices. Similar to the phase one devices, OWL Circle outcomes afford the exploration of previously unarticulated, and unmitigated body-technology desires (eg. Fig.4). Important in both phases is that the technology is imagined, through an embodied discovery process, by the participants.

Leaving the technology to participants' imaginations, rather than providing or proposing technologies with known uses and/or clearly defined parameters, affords wild thinking. Participants envision potential use by engaging in open imagining from and through the body and desire rather than having their thinking constrained or initiated by technological capabilities or project requirements. [2, 51, 52]

Asking someone to imagine yet-to-be-imagined technologies puts a strain on their ability to bring ideas into being. "What do you really want, if you could have anything?" is an awful question, and mostly results in simple, modest answers [2]. The OWL processes attempt to blot out the most immediate answers, so that we might access more instinctual, and perhaps less plausible responses that challenge and stretch what we consider to be viable; that leapfrog the adjacent possible [28, in 26]. The adjacent possible speaks to that which is right next to us, that we can imagine, that which, once imagined, we can bring into being. It speaks to, through and from existing knowledge. The OWL project asks how we might enlarge and move through the adjacent possible very quickly, even bypass it, to arrive at what we cannot yet conceive of. By leveraging embodied discovery in this process, the project affords new ways of conceptualizing. It brings hand and mind together, the divorce of which is said to put a strain on the human psyche [29]. It also leverages the creative power of random, episodic, silent thought, or REST [3].

When the mind is at REST, the association cortices are particularly active. Neuroimaging studies suggest that highly creative individuals have more intense activity in association cortices when performing tasks that

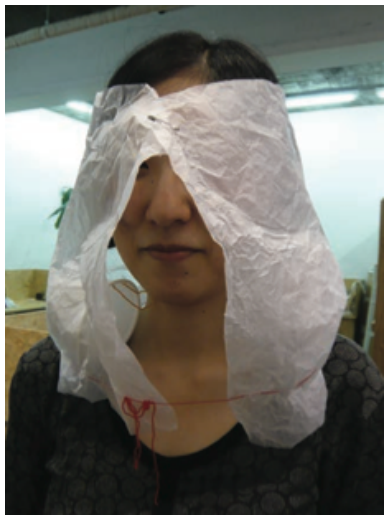


Figure.4 *OWL Circle* outcomes

challenge them to "make associations" [3]. While it remains an open question, whether OWL supports or strengthens creativity in participants, leveraging REST in place of active interrogation, and bringing hand and mind together through embodied processes, seems to engender tranquility: participants are focused, efficient, relaxed and also gently energetic. Thinking becomes an emergent bodily process, allowing participants to access knowledge, expertise and/or connoisseurship that otherwise eludes articulation [53].

In the sense of Dewey's 'experience' [12], the OWL project works with ideas as a 'process of becoming' that can allow what may appear as chaos to create order and pattern through embodied discovery. Unknowing is pivotal to this process. Butler claims we must: "risk ourselves precisely at moments of unknowingness, when what forms us diverges from what lies before us, when our willingness to become undone in relation to others constitutes our chance of becoming human" [8]. The OWL project facilitates this kind of risk taking, providing a temporary space in which participants might 'become'. It does so by tightly coupling cognitive and kinaesthetic load, confronting desires, bodies and dreams about technology, naming desires and giving them form, but also giving account from the place Butler speaks of, where we become and remain human.

Discussion

Each of the works discussed here bring participants, through poetic-kinaesthetic engagement, to new modes and patterns of bodily thinking and experience, engendering states that neuroscientists discuss as promoting plastic change. Some of the applications proposed are pragmatic, others fantastical. A more nuanced and detailed discussion is provided elsewhere [48]. What is important here is to understand how (a) poetic-kinaesthetics engender heightened states of awareness during, as well as after the activity; (b) poetic-kinaesthetics foster enhanced engagement that may improve outcomes in a range of contexts, over time; and (c) poetic-kinaesthetics afford "residual spin off of movement": feelings of aliveness, in a personal and existentially vibrant sense, such as described by Sheets-Johnstone in relation to active embodied engagement [42].

Michael Merzenich, the driving force behind scores of neuroplastic innovations [33], considers paying close attention integral to achieving long-term plastic change [14, 30]. He speaks of the importance of punishment and reward when designing activities to prompt such change, as "the aim is to keep people engaged in what would otherwise be very boring activities" [14]. Poetic-kinaesthetics afford an intriguing response to both of these challenges. As discussed in the case studies, poetic-kinaesthetics prompt heightened states of attention. They are intriguing, and afford extended engagement, and the systems are open, so their use may be customized to achieve targeted results to support specific movement or thinking outcomes, for people with a range of abilities or challenges. Poetic-kinaesthetics begin with the body and use ideas of enchantment, ambiguity and play to afford emergent self-knowledge, as well as creative expression and playful physical engagement. They open up new ways of seeing, thinking and generating knowledge about the body, prompting a process of creating and reflecting on new modes and patterns of bodily experience, as facilitated by the interaction between body movement and the effects of the technology [48]. As a result, action, transformation and ongoing narrative

experience evolve in ways that are indirect and surprising, to result in the kinds of juxtapositions and slippages that support multiple interpretations of evolving postural schemas [48].

In "How the body shapes the mind," Gallagher provides an extended discussion of the interrelation of body schema and physical activity, and the benefits of engaging in different types of movement that affect motility and postural schemas [17]. He cites a study by Rock and Harris that demonstrates that where visual information conflicts with proprioceptive input, such as may occur with poetic-kinaeshtetics, adjustments take place in the interpretation of proprioception and the body schema shifts to accommodate what the person is seeing [39]. An ongoing assessment of body schemas plastically affects the brain, impacting physical and mental health and wellbeing [14, 17]. Merleau-Ponty asserts that gesture helps to accomplish thought [32], and Pulvermüller discusses how the interweaving of cognitive centres for language and action [36] may afford cross-modality cortical activation. Physically engaging body-devices may therefore positively impact thought, as well as language and, more broadly, action.

Bennett describes enchantment as being "both caught up and carried away" [7]. She suggests that the disorientation involved is associated with a pleasurable sense of fullness and liveliness that charges attention and concentration: perception and attention are heightened, we are awakened to wonder and to the wonder of life, which may be experienced as enlivening. The combination of emotional attachment and a sense of something "not yet understood" leaves us feeling disrupted but also attentive and curious. According to McCarthy, enchantment engages with paradox and ambiguity, putting "being" in play in an open world. This process contributes to creating depth in a system or object. It affords the possibility of complex, layered interpretation. "When it comes to experiences such as enchantment feelings are as important as thoughts, sensation is as important as cognition, and emotional consciousness is as important as will" [31]. The depth in a system or object allows it to contain within itself the possibility for complex, layered interpretation that may surprise the interpreter. These interpretations then allow traditionally separate categories of experience to live together in a creative response to new technologies. McCarthy argues that it is this depth that supports enchantment in human-computer interaction. I suggest that enchantment confers depth because of the inherent ambiguity. Ambiguity allows for meaning making, as the openness allows a person to infer or apply their own understanding of the world, to interpret and name what they are engaging with [19]. This process creates a spiral relationship, enchantment supporting depth and meaning making, which further supports enchantment, enriching experience and affective attachment, engaging the whole person.

Such enriched engagement is enhanced by the tight coupling of cognitive and kinaesthetic load in carefully designed poetic-kinaesthetic activities. The open question remains whether, in engaging participants in different ways, poetic-kinaesthetic activities can stimulate different kinds of neuroplastic change. Can their engaging nature be leveraged to support targeted neuroplastic change in response to specific cognitive deficits? Or are they only of use to deal more broadly with communication issues and general decline? Answers to these questions will be afforded through a combination of neuroimaging and cognitive studies. The

question then will be, can specific activities, with pragmatic neural outcomes, be designed, and retain their ability to enchant? Research is planned to investigate these questions.

Acknowledgements

Poetic-kinaesthetics were developed within a doctoral thesis, supervised by Melissa Miles and Richard Helmer. Thanks in particular to Richard Helmer for supporting my interest in the neural impact of this work. Thanks also to Tania Splawa-Neyman for editorial assistance.

References

[1] *TEI conference.* http://www.tei-conf.org.

[2] Andersen, K., Wilde, D. Circles and Props: making unknown technology. *Interactions, 19, 3 (2012), 60-65.*

[3] Andreasen, N. C. A Journey into Chaos: Creativity and the Unconscious. *MSM*; 9(1): 42–53. (2011).

[4] Arrowsmith-Young, B. *The Woman Who Changed Her Brain*. Free Press, New York, 2012.

[5] Bach-y-Rita, P. *Brain plasticity as a basis for therapeutic procedures*. Hans Huber, Bern 1980.

[6] Bach-y-Rita, P., Collins, C. C., Saunders, F. A., White, B. and Scadden, L. Vision substitution by tactile image projection. *Nature*, 221, 5184, (1969), 963-964.

[7] Bennett, J. *The enchantment of modern life*. Princeton U. Press, Princeton, 2001.

[8] Butler, J. P. *Giving an account of oneself*. Fordham University Press, NY, USA, 2005.

[9] Carney, D. R., Cuddy, A. J. C., Yap, A. J. Power Posing: Brief Nonverbal Displays Affect Neuroendocrine Levels and Risk Tolerance. *Psych. Science*, 21, 10 (2010), 1363–68.

[10] Clarke, A. C. *Profiles of the Future*. Holt, Rinehart & Winston, New York, NY, USA, 1984.

[11] Danto, A. C. *The transfiguration of the commonplace: a philosophy of art*. Harvard U. Press, Cambridge, 1981.

[12] Dewey, J. *Art as Experience*. Putmans, NY, 1958.

[13] Diamond, M. C. *Enriching heredity: The impact of the environment on the anatomy of the brain*. Free Press, NY, 1988.

[14] Doidge, N. *The Brain That Changes Itself.* Viking Penguin NY, 2007.

[15] Dowler, L. *Improvising on the Ward*. Foundation for Community Dance, UK. Winter 2009

[16] Ellul, J., C. Watkins, N. Ferguson, Barer, D., Row, J. Increasing patient engagement in rehabilitation activities. *Clinical Rehabilitation*, 7, (1993), 297.

[17] Gallagher, S. *How the Body Shapes the Mind*. Oxford University Press, Oxford, 2005.

[18] Gao, Y. and Mandryk, R. L. The Acute Cognitive Benefits of Casual Exergame Play. In *Proc. CHI 2012*. ACM Press, NY (2012)

[19] Gaver, W. Designing for Homo Ludens. *13 Magazine*, 12, (2002), 2-6.

[20] Genzlinger, N. *Learning His Body, Learning to Dance*. The New York Times, NY, Nov 25 2009, C1.

[21] Gibson, J. J. The Theory of Affordances In Perceiving, Acting, and Knowing. Erlbaum, Hillsdale, NJ 1977.

[22] Hebb, D. O. *The organization of behavior.* Wiley & Sons, NY, USA, 1949.

[23] Helmer, R. J. N. Position and Motion Sensing for Sport, Entertainment and Rehab. In *Proc. CIMTEC,* (2008)

[24] Helmer, R. J. N., Mestrovic, M.A., Taylor, K., Philpot, B., Wilde, D. and Farrow, D. Physiological Tracking, Wearable Interactive Systems and Human Performance. In *Proc. ICART,* The Virtual Reality Society of Japan, (2010).

[25] Hewitt-Parsons, S. Unintentional Therapy, Unexpected Results. In *Poc. ArtAbilitation*. Reading University (2006).

[26] Johnson, S. *Where Good Ideas come From.* Riverhead, NY, 2010.

[27] Jordan, J. E. Briggs, A. M., Brand, C. A., Osborn, R. H. Enhancing patient engagement in chronic disease self-

management support initiatives in Australia. *Medical Journal of Australia*, 189, 10, (2008), 9-13.
[28] Kauffman, S. *Investigations*. Oxford U. P., NY, 2000.
[29] Kelly, K. *What Technology Wants*. Viking, NY, 2010.
[30] Kilgard, M. P., Merzenich, M. M. Cortical map reorginization enabled by nucleus basalis activity. *Science*, 279, 5357, (1998), 1714-18.
[31] McCarthy, J., Wright, P., Wallace, J., Dearden, A. The experience of enchantment in human–computer interaction. *Pers. & Ubiq.* 10, (2006), 369–378.
[32] Merleau-Ponty, M. *Phenomenology of Perception*. Routledge & Kegan Paul, London, UK, 1962.
[33] Merzenich, M. USC publications list: http*://profiles. ucsf.edu/ProfileDetails.aspx?Person=5135507*.
[34] Michael Merzenich, et. al. Posit Science: http://www.positscience.com/.
[35] Preminger, S. Transformative art: art as a means for long-term neurocognitive change. *Frontiers in Human Neuroscience*, 6, 96, (2012), 1-7.
[36] Pulvermüller, F., Hauk, O., Nikulin, V. V., Ilmoniemi, R. J. Functional links between motor and language systems. *Neuroscience (EU)*, 21,3, (2005) 793-7.
[37] Ramachandran, V. S., Rogers-Ramachandran, D. Synaesthesia in phantom limbs induced with mirrors. *Royal Society B: Biological Sciences*, 263, 1369 (1996), 377-386.
[38] Renner, M. J. and Rosenzweig, M. R. Enriched and impoverished environments Springer Verlag, NY, (1987).
[39] Rock, I. and Harris, C. S. Vision and Touch. *Scientific American*, 216, 5 (1967), 96-104.
[40] Rosenzweig, M. R., Krech, D., Bennet, E. L., Diamond, M. C. Effects of environmental complexity and training on brain chemistry and anatomy. *Comparative and Physiological Psychology*, 55, (1962), 429-37.
[41] Sheets-Johnstone, M. *The Primacy of Movement*. John Benjamins, Amsterdam, 1999.
[42] Sheets-Johnstone, M. Why Is Movement Therapeutic? *American Journal of Dance Therapy*, 32, 1 (2010), 2-15.
[43] Shklovsky, V. *Art as Technique.* In *Russian Formalist Criticism: Four Essays*. U. Nebraska Press, Lincoln, 1965.
[44] Taub, E., Uswatte, G. and Pidikiti, R. Constraint-Induced Movement Therapy: A new family of techniques with broad application to physical rehabilitation--a clinical review. *Rehabilitation R&D.*, 36, 3, (1999), 237–51.
[45] Varela, F., Thompson, E. and Rosch, E. *The Embodied Mind*. MIT Press, Cambridge, MA, USA, 1991.
[46] Wilde, D. The hipdiskettes : Learning (through) Wearables. In *Proc. OZCHI 2008.* ACM Press (2008)
[47] Wilde, D. Extending Body & Imagination : moving to move. *IJDHD* 10, 1, (2011), 31-36.
[48] Wilde, D. *Swing that thing : moving to move.* PhD. Diss., Monash University and CSIRO, Australia, 2011.
[49] Wilde, D. hipDisk: understanding the value of ungainly, embodied, performative, fun. *Ext. Abstracts CHI 2012*, ACM (2012), 111–120
[50] Wilde, D., Cassinelli, A., Zerroug, A., Helmer, R. J. N., Ishikawa, M. Light Arrays: a system for extended engagement. In *Proc. ICDVRAT* (2010). U. Reading, UK.
[51] Wilde, D., Andersen, K. Doing things backwards: the OWL project. In *Proc. OZCHI 2009*. ACM Press (2009)
[52] Wilde, D., Andersen, K. Part Science Part Magic. In *Proc. OZCHI 2009*. ACM Press (2010)
[53] Wilde, D., Schiphorst T., and Klooster, S. Move to Design • Design to Move. *Interactions*, 18, 4 (2011).
[54] Wressle, E., Eeg-Olofsson, A. M., Marcusson, J., Henriksson, C. Improved Client Participation in the Rehabilitation Process Using a Client-Centred Goal Formulation Structure. *Rehab. Med.*, 34, (2002), 5-11.