What allows us to kinesthetically empathize with motions of non-anthropomorphic objects?

Kensho Miyoshi

Abstract: *The physical movements of designed objects not only have utilitarian purposes but also make us experience the diverse kinetic sensations. Such an imaginative projection of one's own embodied sensation to observed movements is called "kinesthetic empathy". Despite the majority of its research focused on observation of human movements, little is known about how kinesthetic empathy works with the movements of everyday, non-anthropomorphic objects. Through my close observations, I propose a new concept of "kinesthetic elements" that help us understand the kinesthetic potential of object motions beyond somatic dissimilarity.*

Keywords: *kinesthetic empathy, kinetic design, kinesthetic element, design research.*

1. Introduction

Kinetic movements appear in diverse scenes of designed objects and environments—for example, in the tick-tock of clock hands; the rotation of fan blades; pop-up toasters; the swaying of curtains; and the sliding, revolving and folding of automatic doors. Each movement not only has its utilitarian purpose, but also takes on unique aesthetic qualities through its forms, dynamics and contexts. Some movements appear light, effortless and graceful, while others seem heavy, stiff and awkward.

My PhD research began with my initial interest in such qualitative aspects of object movements. The motivation derives from my background in human-robot interaction (HRI) research, which focused on autonomous aerial robots[1,2,3] and practices in kinetic art.[4,5] The aesthetic, poetic and empathic experiences in observing physically dynamic objects in various contexts triggered an interest in exploring the qualitative aspects of object movements and their potential application beyond art and engineering, and into the realm of design. My foundational studies afforded me the possibility of deeper exploration into the area where *kinesthetic empathy*

1 Miyoshi, Kensho, Ryo Konomura, and Koichi Hori. "Above Your Hand: direct and natural interaction with aerial robot." In *ACM SIGGRAPH 2014 Emerging Technologies*, p. 8. ACM, 2014.

2 Miyoshi, Kensho, Ryo Konomura, and Koichi Hori. "Entertainment multi-rotor robot that realises direct and multimodal interaction." In *Proceedings of the 28th International BCS Human Computer Interaction Conference on HCI 2014-Sand, Sea and Sky-Holiday HCI*, pp. 218-221. BCS, 2014

3 Balloon 2 Blimp. 2013. http://diydrones.com/profiles/blogs/ballon-2-blimp?xg_source=activity

4 Hamon Clock. 2013. Available: https://miyoshikensho.com/en/ham.html

5 Puwants, in collaboration with Kosei Komatsu. 2014. https://miyoshikensho.com/en/puw_n.html

meets *kinetic design*.

Although the definition of kinesthetic empathy varies depending on the context,[6] it essentially refers to our innate capacity and sensitivity to simulate the sense of movement of the entities one observes, such as humans, animals and objects. The notion of kinesthetic empathy was a research theme in a recent research project, *Watching Dance: Kinesthetic Empathy*, which is documented in a book titled *Kinesthetic Empathy in Creative and Cultural Practices* by Reynolds and Reason.[7] Despite their primary focus on human movement in dance and theater, as opposed to designed objects, the concept provided me with a perspective to understand what I had attempted, but failed to articulate, regarding the aesthetic experience of watching movements. This paper presents my recent findings, which build upon my preceding exploration.[8]

2. Background

Kinetic design

I deliberately use the open term *kinetic design* to mean designed objects such as products, furniture and interior in which physical movements serve either practical or aesthetic purposes. The notion of movement in my research, despite its designerly purpose, follows what Gabo and Pevsner called "movement itself" in their *Realist Manifesto*[9] in 1920. "Movement itself" refers to the physically dynamic movement of objects, rather than to the movement of Futurism, which attempted to recreate the sense of motion by using physically static media and optical effects.[10]

Kinetic design consists of objects with a variety of motions, such as automatic and continuous (e.g. mechanical clocks), automatic and reactive (e.g. automatic doors) and manual (e.g. non-automatic doors), among others, although these categories are neither discrete nor comprehensive. Everyday objects such as pop-up toasters, mechanical clocks and fans are typical examples of kinetic design. The potential of this type of design has been explored in many ways, including aesthetic,[11,12,13] interfacial,[14,15] communicative[16] and emotional.[17] The *kinesthetically empathic* potential of object movements, however, has rarely been considered. Through the lens of kinesthetic empathy, our empathic and embodied response to the behavior of objects can be revealed, which will provide a new perspective on how we "feel" them bodily, as opposed to how

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6 Ibid.

7 Reynolds, Dee, and Matthew Reason, eds. *Kinesthetic empathy in creative and cultural practices*. Intellect Books, 2012

8 Miyoshi, Kensho. "Where Kinesthetic Empathy meets Kinetic Design." In *Proceedings of the 5th International Conference on Movement and Computing*, p. 32. ACM, 2018

9 Gabo, Naum, and Noton Pevsner. *The Realistic Manifesto* (1920). Aspen, 1967.

10 Rickey, George W. "The morphology of movement: a study of kinetic art." *Art Journal 22*, no. 4 (1963): 220-231.

11 Yoshimoto, Hideki. "Pulse and rhythm: exploring the value of repetitive motion as an element of design." PhD diss., Royal College of Art, 2015.

12 Niedderer, Kristina. "Exploring elastic movement as a medium for complex emotional expression in silver design." *International Journal of Design* 6, no. 3 (2012).

13 Moloney, Jules. *Designing kinetics for architectural facades: state change*. Routledge, 2011.

14 Ishii, Hiroshi, and Brygg Ullmer. "Tangible bits: towards seamless interfaces between people, bits and atoms." In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, pp. 234-241. ACM, 1997.

15 Parkes, Amanda, Ivan Poupyrev, and Hiroshi Ishii. "Designing kinetic interactions for organic user interfaces." *Communications of the ACM 51*, no. 6 (2008): 58-65.

16 Ju, Wendy, and Leila Takayama. "Approachability: How people interpret automatic door movement as gesture." *International Journal of Design* 3, no. 2 (2009): 1-10.

17 Weerdesteijn, Jeske MW, Pieter MA Desmet, and Mathieu A. Gielen. "Moving design: To design emotion through movement." *The Design Journal* 8, no. 1 (2005): 28-40.

we process them intellectually. Whereas the contemporary scholarship on kinesthetic empathy is mostly concerned with observing human movement,[18,19,20,21,22] not much is known about the ways in which kinesthetic empathy works with movements of non-human entities.

Kinesthetic empathy with non-human entities

The origin of kinesthetic empathy dates back to 1873 when Robert Vischer, a German aesthetician, used the term *Einfühlung* (later translated into English as empathy) to denote the aesthetic experience of projecting oneself onto an object.[23] Kinesthetic response was considered to result from a conscious attention to objects of various kinds. Sixteen years later in France, according to Popper's thorough book on kinetic art,[24] Paul Souriau, who was a French philosopher, established the first and in-depth study into the aesthetics of physical movement of humans and animals. Although the term was not used explicitly in his book *The Aesthetics of Movement*,[25] kinesthetic empathy was, in effect, the crux of his method of aesthetic observation and reasoning. Souriau explores various aesthetics of animals' movements through his imaginative projection of himself onto them, beyond the gap in the somatic structure. Later, Michael Polanyi, who is known to be the father of the well-known concept, *tacit knowledge*, also explored *indwelling*, which refers to the tacit perception of objects and events through the medium of our body.[26] While these views share a similar focus, a disagreement remains in terms of the controllability of kinesthetic empathy. Vischer argued that kinesthetic empathy results from conscious effort and imagination. In contrast, for Polanyi, *indwelling* was a type of tacit knowing, "which we are quite incapable of controlling."

Several studies have explored kinesthetic empathy with inanimate objects, such as chairs in a visual installation space,[27] human-scale objects inhabited and animated by performers,[28] and interactive environments,[29] among others. While these studies provide detailed consideration of each case, their transferability to design remains open. Laban Movement Analysis,[30] one of the most pioneering frameworks for motion analysis, was expected to be of some use. However, being heavily grounded in the structure of the human body, it was not possible to easily apply the framework to non-anthropomorphic objects.

In addition to these insights from philosophy and aesthetics, recent studies have provided

18 Reynolds and Reason (2012).

19 Parviainen, Jaana. "Kinaesthetic empathy." (2003).

20 Moen, Jin. "KinAesthetic movement interaction: designing for the pleasure of motion." (PhD diss., KTH Royal Institute of Technology, 2006).

21 Reason, Matthew, and Dee Reynolds. "Kinesthesia, empathy, and related pleasures: An inquiry into audience experiences of watching dance." *Dance research journal* 42, no. 2 (2010): 49-75

22 Jola, Corinne, Lucie Clements, and Julia F. Christensen. "Moved by stills: Kinesthetic sensory experiences in viewing dance photographs." *Seeing and Perceiving* 25 (2012): 80-81.

23 Vischer, Robert. "On the optical sense of form: A contribution to aesthetics." *Empathy, form, and space: problems in German aesthetics* 1893 (1873): 89-124.

24 Popper, Frank. *Origins and development of kinetic art*. (New York Graphic Society, 1968).

25 Souriau, Paul. *The aesthetics of movement*. (Univ of Massachusetts Press, 1983).

26 Polanyi, Michael. *The tacit dimension*. (University of Chicago press, 2009).

27 Cuykendall, Shannon, Ethan Soutar-Rau, Karen Cochrane, Jacob Freiberg, and Thecla Schiphorst. "Simply spinning: Extending current design frameworks for kinesthetic empathy." In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (*ACM, 2015), pp. 305-312.

28 Gemeinboeck, Petra, and Rob Saunders. "Movement Matters: How a Robot Becomes Body." In *Proceedings of the 4th International Conference on Movement Computing* (ACM, 2017), p. 8.

29 Reynolds and Reason (2012).

30 Bartenieff, Irmgard. *Body movement: coping with the environment.* (Reading: Gordon and Breach Science Publishers, 1980).

scientific understandings of kinesthetic empathy. First, there is a strong parallel between kinesthetic empathy and the mirror neuron system, originally discovered in the 1990s.[31] Mostly by using the fMRI technique, recent neurological studies have identified humans' empathic responses to non-human and non-anthropomorphic objects such as character animations,[32] vacuum cleaner robots,[33] and abstract animations.[34] Second, kinesthetic empathy is also informed by several fields such as perceptual psychology,[35,36] ecological psychology[37] and embodied cognition.[38,39] The concept of affordance in particular has an intricate relation to kinesthetic empathy. It has been indicated that internal kinesthetic stimuli can occur when a certain action is invited by the external objects or environments, even if no explicit action results.[40] Affordance invites imagining how to move in order to touch or grasp an object, for example, whereas kinesthetic empathy consists of projecting oneself onto an object and imagining how it would "feel" kinesthetically. While different types of simulation exist, they are difficult to distinguish on the phenomenological level. This confusion has also occasionally been observed in my ongoing participatory practice where designers learn about the concept of kinesthetic empathy and apply it to analyzing and designing the quality of object movement. Third, anthropomorphism is a concept that closely resembles, and is often confused with, kinesthetic empathy. My studies so far indicate that the degree of anthropomorphism can affect kinesthetic empathy. The critical difference between the two concepts is that kinesthetic empathy is about internal kinesthetic stimuli in the observers when they empathize with an observed movement, whereas anthropomorphism is about how we find human-likeliness in objects.[41,42,43]

These scientific theories are expected to be relevant to my research; however, the specific meaning in my research gradually becomes clear through practice. Overall, the concept of kinesthetic empathy is highly interdisciplinary, yet its connection to design is largely unexplored. This paper presents the early stage of my exploration into the following research questions. What can designers learn about humans' empathic and embodied reaction to object movements through the lens of kinesthetic empathy? How can designers apply the knowledge to analyzing and exploring the quality of object movements?

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31 Polanyi (2018).

32 Power, Patrick. "Character Animation and the Embodied Mind—Brain." *Animation* 3, no. 1 (2008): 25-48.

33 Hoenen, Matthias, Katrin T. Lübke, and Bettina M. Pause. "Non-anthropomorphic robots as social entities on a neurophysiological level." *Computers in Human Behavior* 57 (2016): 182-186.

34 Engel, Annerose, Michael Burke, Katja Fiehler, Siegfried Bien, and Frank Rösler. "How moving objects become animated: the human mirror neuron system assimilates non- biological movement patterns". *Social neuroscience*, 3(3-4), (2008): 368-387.

35 Bartley, S. Howard. "Principles of perception." (1958).

36 Arnheim, Rudolf. *Art and visual perception*. (Univ of California Press, 1974).

37 Gibson, James J. *The ecological approach to visual perception: classic edition*. (Psychology Press, 2014).

38 Clark, Andy. *Supersizing the mind: Embodiment, action, and cognitive extension*. (OUP USA, 2008).

39 Blakeslee, Sandra, and Matthew Blakeslee. T*he body has a mind of its own: How body maps in your brain help you do (almost) everything better*. (Random House Incorporated, 2007).

40 Freedberg, David, and Vittorio Gallese. "Motion, emotion and empathy in esthetic experience." *Trends in cognitive sciences* 11, no. 5 (2007): 197-203.

41 Blythe, Philip W., Peter M. Todd, and Geoffrey F. Miller. "How motion reveals intention: Categorizing social interactions." (1999).

42 Bartneck, Christoph, Takayuki Kanda, Omar Mubin, and Abdullah Al Mahmud. "Does the design of a robot influence its animacy and perceived intelligence?." I*nternational Journal of Social Robotics* 1, no. 2 (2009): 195-204.

43 Mori, Masahiro, Karl F. MacDorman, and Norri Kageki. "The uncanny valley [from the field]." *IEEE Robotics & Automation Magazine* 19, no. 2 (2012): 98-100.

3. Approach

My research belongs to what Phillips and Pugh call *exploratory research*, where little is known about the problem at hand and researchers have to develop new methods and theories and examine whether the existing methods are applicable.[44] Christopher Frayling differentiated three types of research in art and design: research *into, for* and *through* art and design.[45] Though all three are present in my research, it is research *through* design that largely contributed to the development of my research.

What follows is my exploration into kinesthetic empathy with the movements of physical, non-anthropomorphic objects and the process in which I developed two original concepts: *kinesthetic representation* and *kinesthetic elements*. The methods of making, observing objects and reflecting on my own practices[46] were used. For simplicity, in the following discussion I define *direct* kinesthesis and *indirect* kinesthesis (kinesthetic sensation) as follows. A *direct* kinesthesis arises from people's own bodily movements, whereas an *indirect* kinesthesis refers to a sensation of kinesthetic empathy with external motions.

4. Kinesthetic representation

Kinesthetic empathy is, essentially, an association of an observer's own kinesthetic sensation, whether a real memory or imagination, with observed movements. However, even if observers experience kinesthetic empathy, its sensation is often difficult to verbalize, which became an obstacle to exploration. Through trial and error, I developed a method of communicating the sensation of kinesthetic empathy through body gestures, which I termed *kinesthetic representation*.

Figure 1 presents my first attempt to express my own kinesthetic empathy with the spinning motion of a cone-shaped sculpture in an embodied, non-verbal manner. My static posture, leaning sideways, was aimed at expressing the body posture, which gave me a *direct* kinesthetic sensation similar to the kinesthetic empathy with the sculpture—the tensional feeling of balance and imbalance. This translation from internal sensations to external postures proved to be an effective tool to communicate with other people the ineffable sensation of kinesthetic empathy.

Figure 1: Left: my sketch of the cone-shaped sculpture; *Careful I* (2009) by glass artist and researcher Heike Brachlow.[47] Middle: my sketch of the sculpture in motion. Right: my body posture that expresses my kinesthetic empathy with the movement.

44 Phillips, Estelle, and Derek Pugh. *How to get a PhD: A handbook for students and their supervisors*. (McGraw-Hill Education, 2010).

45 Frayling, Christopher. "Research in art and design." (1993).

46 Schon, Donald. "The reflective practitioner." (1983).

47 Careful I (2009) by glass designer and researcher Heike Brachlow. Video available: http://www.heikebrachlow.com/HB_Frameset.htm

To better articulate kinesthetic empathy sensations, dynamic body gestures were attempted. Figure 2 ilustrates an example of kinesthetic representation, which I performed (on the right) with the aim of expressing my kinesthetic empathy with *Balance Machine*, a kinetic sculpture I created (on the left). The hammer attached at the top is lifted by the motor and released. It then hits the body of the sculpture and makes it literally "almost fall over." It was created to gain an in-depth understanding of the movement and mechanism of *Machines That Almost Fall Over*[48] (2008), the kinetic sculpture by Boston-based artist Michael Kontopoulos, by replicating the movement from scratch. I performed the specific body gesture, which provided the *direct* kinesthesis closest to the sensation of kinesthetic empathy with the sculpture's motion.

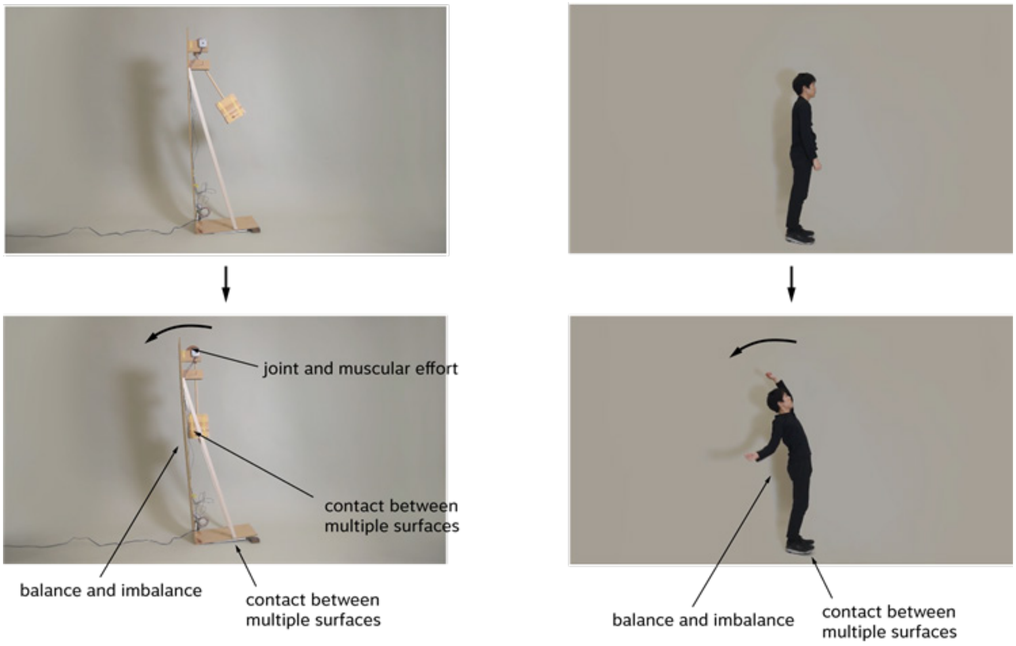

Figure 2: Upper-left: *Balance Machine* standing upright. Bottom-left: *Balance Machine* tilting to the left. Upper-right: my kinesthetic representation with the sculpture standing upright. Bottom-right: my kinesthetic representation with the sculpture tilting. The annotations are my observation and reflection that led to the idea of kinesthetic elements.

Another type of kinesthetic empathy exists between one who performs a kinesthetic representation of an object motion (Observer-A) and another who observes A's kinesthetic representation (Observer-B). Figure 3 depicts the three kinds of kinesthetic empathy present in the communication enabled by kinesthetic representation. Observer-B compares his/her kinesthetic empathy, both with Observer-A's kinesthetic representation and with the object movement, to explore the kinesthetic potential Observer-A is attempting to communicate. This communication should be further clarified by using verbal discussions between A and B than merely relying on the gestures.

48 Machines That Almost Fall Over (2008). http://www.mkontopoulos.com/portfolio/machines-that-almost-fall-over/

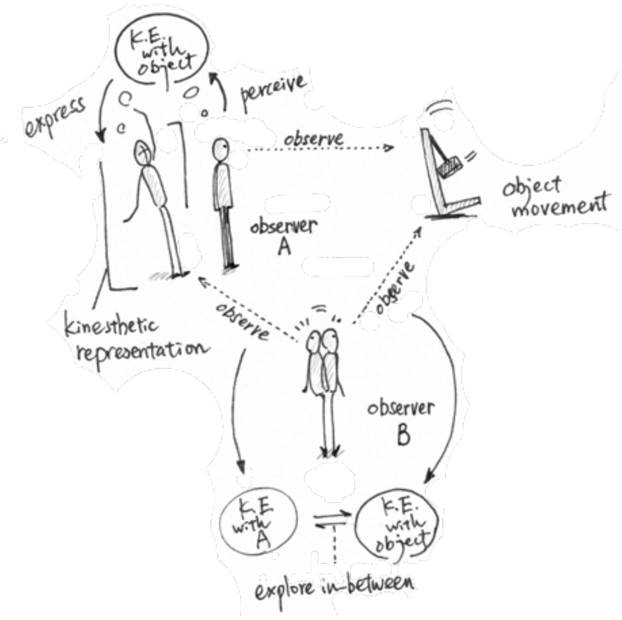

Figure 3: Multiple types of kinesthetic empathy present in the system of kinesthetic representation; "K.E." in the illustration means "kinesthetic empathy."

The *direct* kinesthesis experienced while performing the kinesthetic representation and the referenced *indirect* kinesthesis are not exactly the same. However, the exploration through bodily movement enabled me to articulate various aspects of my kinesthetic empathy with the sculpture. Borrowing Schön's terminology,[49] I explored by performing the action (reflection-in-action) as well as reflecting on it by watching the video recording of my own movement (reflection-on-action). Through this process, four facets of kinesthetic senses were identified.

First, and most obviously, the sense of balance is present. My kinesthetic representation features balance and imbalance by leaning backward to the point at which I nearly fall over. The nuance of kinesthetic sensation exists even in the choice of the direction of leaning—backwards, not forwards. The sculpture supports itself with the base stretched to the right, but, on the other hand, the left side is empty and defenseless. This reflects the human ability to better resist imbalance forwards more than backwards, because of the direction of the feet stretched out from the heels.

Here, the attention shifts from balance to tactility. The sculpture wobbles after regaining balance, and the oscillation gradually decreases. The physical contact between the base and the floor is reflected in my kinesthetic representation where my feet are touching on and off the floor. These two senses of contact are similar but never the same because of the gap in materiality, weight and dynamics.

While these two aspects—the balance of leaning and the tactility of the base—are reflected in my kinesthetic representation, there are other sensations that are not clearly articulated. One is the slightly painful collision between the hammer and the body of the sculpture. The others are the sense of effort in the motion of lifting the hammer and the sense of articulation in which the weight is received by one specific point (the joint supporting the root of the hammer). As a combination, the movement reminds me of the sense of muscular effort around the shoulder when lifting a heavy weight held by hand and keeping the arm extended.

49 Schön (1983).

Here, kinesthetic representation becomes a useful tool to explore the kinesthetic empathy experienced with not only the artifacts I created but also existing practices and natural phenomena. A possible confusion, that needed to be avoided, was that kinesthetic representation could be interpreted as a superficial imitation of the object movements or mere *kinetic* (without *esthetic* = sensory, perceptual) representation. I needed to make my intention clear each time I presented kinesthetic representation in textual, digital or oral form.

I used kinesthetic representation to analyze the movement qualities of over 50 types of objects. While conducting this research, any objects in motion such as everyday objects, natural phenomena and existing kinetic artworks became the targets of observation. When I found something especially intriguing, I attempted to create similar mechanisms myself to extend the observation. While kinesthetic representation was conceived as a tool to communicate with other people the experienced kinesthetic empathy, the comparison between direct and indirect kinesthesis allowed me to understand kinesthetic responses at a higher resolution. Further analysis revealed several commonalities between the fragments of kinesthetic empathy sensations, which I termed kinesthetic *elements*. These elements were identified in an organic and reflective manner, where one element served as the lens to construct others. That kinesthetic representation has failed to cover some elements does not mean a real failure but a process of exploration.

5. Developing kinesthetic elements

When identifying the elements, I often referenced anatomy[50] and perception[51] to learn about the mechanisms of human organs and senses. Perceived kinesthetic qualities cannot be fully reduced to the workings of the organs; however, they are mutually inseparable. At the beginning, four types of kinesthetic elements emerged: *balance, articulation, tension* and *haptic*. The formulation of this idea was inspired by the so-called "five senses." Although I find this phrase misleading, as it sounds to some as if humans have merely five senses, I wondered whether, if at all, something equivalent to the "five senses" existed in kinesthetic empathy. Through this question, the four elements emerged from the accumulation of my observations.

Balance

We have a tacit understanding of how objects balance and stand on the ground, just as we know how to stand upright and remain stable. Balance is of high necessity for human perception, both physically and psychologically.[52] Observing an object at in equilibrium, for example a cuboid placed upright on the floor (Figure 4, left), may not make us experience explicit kinesthetic empathy. Once the cuboid becomes imbalanced (Figure 4, right), however, we can easily understand the sense of imbalance and imagine the kinesthetic sensations of keeping a similar posture.

What strikes us is the accuracy and immediacy of our intuitive, perceptual ability to sense balance in observed objects.[53] The kinesthetic empathy experienced here may be compared with, for example, the feeling of leaning in a direction, being pushed off-balance suddenly without warning, or sitting on a chair and trying to balance on the legs of the chair.

50 Saladin, K. *Anatomy and physiology: The unity of form and function*. 2007. (Ohio: McGraw-Hill, 2010).

51 Bartley (1958)

52 Dondis, Donis A. *A primer of visual literacy*. (MIT Press, 1974): 22.

53 Ibid.

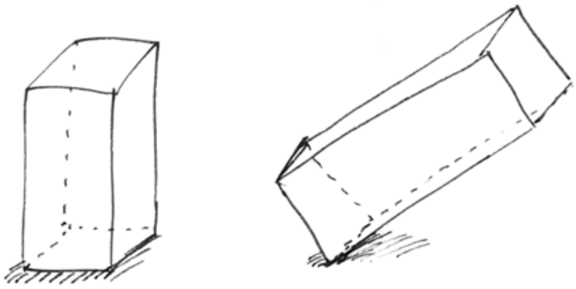

Figure 4: A cuboid standing upright (left) and tilting sideways (right).

The sense organ with which we perceive the condition of our body in relation to the gravitational field is called the vestibular system.[54] It is the non-auditory part of the inner ear that functions as the sense organ for this mechanism and detects the two major aspects of the gravitational force: change in motion, or acceleration, and the static posture of the head. The vestibular sense is often integrated with other parts of the body: vision, the tactile sense and even auditory sense.

Articulation

Our bodies have various articulations: shoulders, backbones, wrists, fingers, knees and necks. An articulation, also called a joint, is a connection between bones in the body that link the skeletal system into a functional whole. They are constructed to move within certain degrees and directions.[55] Each joint contributes to a unique kinesthetic sense as it comprises of different components, such as tendons, and it also connects with different muscles. Nonetheless, we all have a coarse understanding of what the movements of joints feel like which can be projected onto movements of similar structures.

In sports science a double pendulum, a pair of rigid bodies joined with a hinge and hanged from either side of its edges (Figure 5, left), is used as a dynamic model of our limbs.[56,57] Out of the chaotic movements that the pendulum creates, several patterns appear to be kinesthetic empathic. One familiar pattern of motion appears when the pendulum falls from a high position in a folded shape, reaches the bottom in a stretched condition, and then suddenly bounces up. We might project the action of swinging a golf club or a tennis racket, which embraces the kinesthetic sense of speedily stretching an arm to the point where the elbow can no longer bend. It is the impulsive pause and the sense of skeletal limitation in the elbow, the centrifugal force in the whole limb, the feel of the blood being pushed to the edge and the elasticity in bouncing the arm back. It is also noticeable that we do not necessarily experience explicit kinesthetic empathy with all the moments of the pendulum movement. A degree of similarity and dissimilarity, and thus how vividly we can kinesthetically empathize, seems to exist.

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54 Bartley (1958): 365

55 Saladin (1998): 247

56 Bazargan-Lari, Y., A. Gholipour, M. Eghtesad, M. Nouri, and A. Sayadkooh. "Dynamics and control of locomotion of one leg walking as self-impact double pendulum." *Control, Instrumentation and Automation (ICCIA)*, 2011 2nd International Conference (IEEE, 2011): 201-206.

57 Yamada, N. *What makes the movement of top athletes different: The secret of the eminent athletes revealed by sports science* (title translation by me). (Kagaku Dojin. Published in Japanese, 2011)

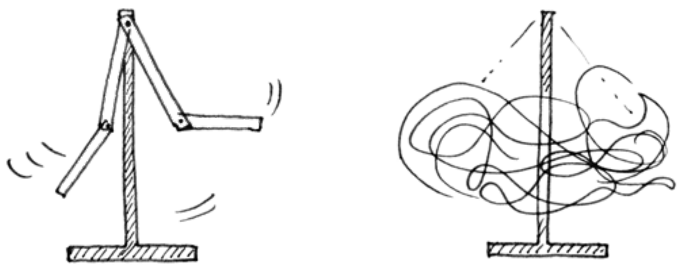

Figure 5: A double pendulum (left) and the trace of its chaotic movement.

Tension

Elastic structures can contain physical tension in their bodies through deformation. "Whether we are dealing with a bent steel blade, a sheet of rubber, a funhouse mirror, an expanding bubble, or the rising emotion of a heated argument, there is always a forceful deviation from a state of lower tension in the direction of tension increase."[58] We understand the elasticity of the material through touching, holding, bending, twisting and so forth. However, it is also possible to estimate the amount and nature of tension by simply watching the behavior of the material that results from either external force or its own weight. The more familiar the material is to the observer, the easier this estimation becomes.

One could project the sensation of muscular tension—one of the major sources of kinesthetic sense—onto an observed elastic, transformative movement (Figure 6). Muscular tension and release are present in a great diversity of our daily movement, such as respiration, locomotion (walking or running) and the manipulation of tools (gripping a pen, rotating a door knob or flipping food in a frying pan). All sensations of this kind create the repertoire of our kinesthetic sense of *tension*.

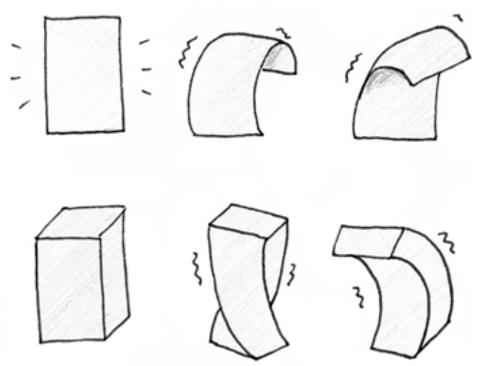

Figure 6: Transformation of 3D objects. Different forms have different ways of accumulating and releasing physical tension.

Bending Sculpture[59] (Figure 7) is one of the artifacts that allow us to perceive the *tension* element. If one taps softly on the sphere, the fiber continues to bend up and down for a while because of the balance between the weight of the ball and the elasticity of the rod. Given the flexibility of the motion, our kinesthetic sense closest to this increase and decrease in the fiber's tension could be the muscular tension along the backbone, for example the tension on the back

58 Arnheim (1956): 428

59 Video available: https://www.youtube.com/watch?v=G33W2rn1hlI

in bending the upper body forwards. The slightly anthropomorphic shape of the sculpture might affect the kinesthetic empathy response.

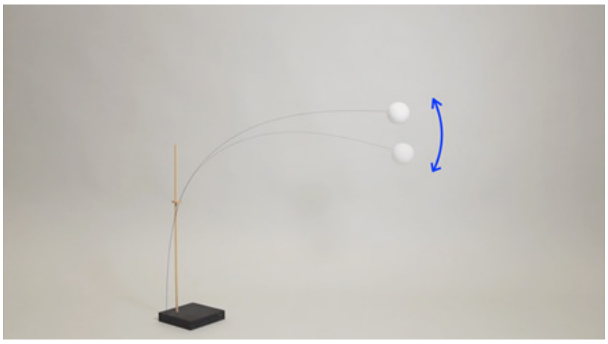

Figure 7: *Bending Sculpture*, made of carbon fiber, a foam sphere and a wooden base. The blue arrow indicates the movement.

Haptic

While the previous three elements are mostly about internal stimuli, this element, haptic, concerns physical contact between surfaces. By seeing and hearing the touch between objects (e.g. a glass falling onto the floor or a door slammed shut), we can tacitly imagine the sense of materiality, dynamics and shapes of the colliding surfaces. Figure 8 depicts a simple visual experiment in which collisions of various abstract shapes and surfaces can allow us to simulate diverse types of *haptic* empathy. In the case of the *Balance Machine*, one may perceive the *haptic* element in observing the collisions between the bottom of the sculpture and the floor and between the hammer and the wooden structure.

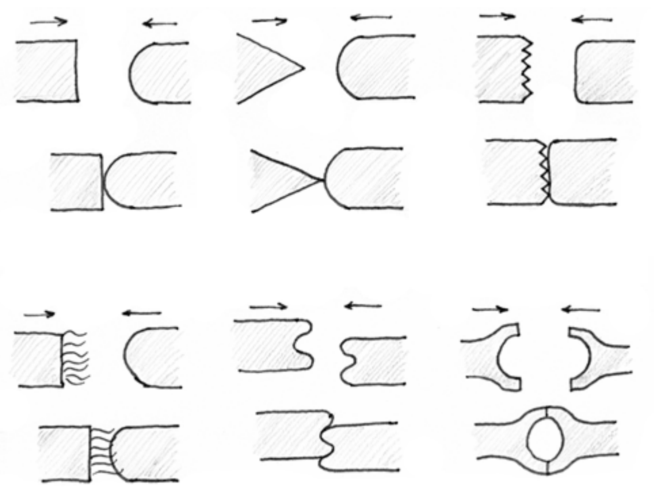

Figure 8: Simple visual experiment of the *haptic* element. Imagining two surfaces colliding can allow us to simulate various haptic sensations.

A number of studies have revealed that a human observer can easily simulate the haptic sensation an observed person is experiencing. For example, "watching the movie scene in which a tarantula crawls on James Bond's chest can make us literally shiver—as if the spider crawled on our own chest."[60] Caravaggio's *Incredulity of Saint Thomas* (1601) can allow viewers to feel as

60 Keysers et al., (2004): 335.

if their skin is penetrated.[61]

In addition, the study by Keysers et al.[62] provides scientific evidence that we also experience a vicarious haptic sense when observing non-anthropomorphic objects. The parts of the brain responsible for sensing bodily sensations such as pressure, pain, or warmth, are activated as if our bodies were subjected to tactile stimulation, not only when we are touched, but also when we observe two non-living objects touching each other are shown (rolls of paper towels and binders being touched by a stick were used as examples). The extent to which similar neurological reactions could be triggered by other objects and contexts remains open. Nevertheless, at the very least, it supports the views such as Vischer's *Einfühlung* and Polanyi's tacit knowing.

6. Reflection

The four elements explained a wide range of kinesthetic empathy with object movements, but how did they emerge at all? It is difficult to explain the exact process of the conception, as it was intuitive rather than logical. In fact, it is one of the greatest leaps that occurred in this research; however, I could post-rationalize the process as follows.

In my PhD research, the observation of movements was no longer an intentional act conducted as "research" but embedded in my everyday life. Especially since encountering the work by Reynolds and Reason,[63] I searched for a pattern in the kinesthetic empathy with object movements. At the same time, this exploration itself has presumably made myself more perceptive to the kinesthetic aspects of motions. I accumulated the tacit understanding of kinesthetic movements through kinesthetic representations but could not yet externalize it in a manner that makes sense to myself or others. Finally, the idea of "five senses" inspired me to identify a pattern, which turned out to be the four kinesthetic elements. It is clear that my thinking was based on literature regarding perception,[64] embodied cognition[65] and anatomy.[66]

According to my observation, it is fairly common for multiple elements to be perceived when observing one movement; this finding is also supported by the result of my ongoing workshops. The idea of kinesthetic elements becomes an important key to understanding kinesthetic empathy beyond somatic dissimilarities. The elements are, as it were, fragments of our embodied memories, whether real or imagined, that could spark when we find similar features in observed physical phenomena, just as mirror neurons work.

The problem of the four elements concerns the dynamics of movements. The *balance* element derives from the change of attitude of an object, while the *articulation* and *tension* elements derive from the transformation of an object; the *haptic* element derives from contact of multiple surfaces. None of these elements were meant to specifically articulate the kinesthetic empathy that results from observing a change in speed/direction of objects that neither change their attitude, transform, nor touch other objects. For example, looking at an object that is moving in a certain direction at a constant speed and then suddenly decelerates and stops (e.g. a door's movement[67] in Figure 9), observers may similarly feel the sense of a sudden stop or even physical

61 Freedberg & Gallese (2007): 201.

62 Keysers et al. (2004).

63 Reynolds and Reason (2012).

64 E.g. Bartley (1958) and Gibson (1979).

65 E.g. Blakeslee & Blakeslee (2007)

66 Saladin (1998)

67 A sliding door suddenly decelerates. https://www.youtube.com/watch?v=TIZXYiYQhkI

effort to cushion the sudden inertia. This could be likened to the sensation experienced when one is cycling and suddenly brakes.

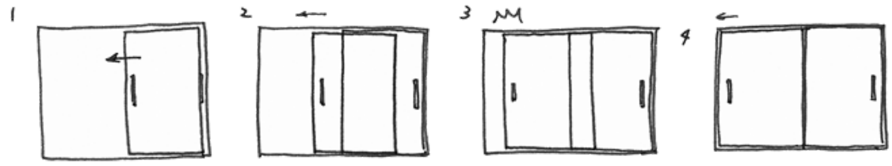

Figure 9: A sliding door.

The limitation of the four elements became clearer as I continued my observation and applied the elements to various object motions. This has led me to the next phase, considering the possibility of new kinesthetic elements for dynamics. This does not necessarily require new objects to observe; those I used for prior observations can be observed through a new perspective, which would lead to finding more clues about the aspect of dynamics. In terms of the benefit of such a generative way of articulating kinesthetic elements, the bottom-up approach allows the framework to be grounded in the phenomenon in question rather than borrowing a framework developed in another context (e.g., Laban Movement Analysis). Also, it perhaps reflects my own sensitivity to the kinesthetic dimension of physical phenomena. This indicates that the sensitivity is what designers can "learn" to acquire and potentially use for designing movements—the educational potential of the framework.

7. Conclusion

In this paper, I proposed a new space for exploration where kinesthetic empathy meets kinetic design. I also illustrated my first, yet substantial, step through my observations. As the literature review suggests, movement has received an increasing amount of attention in the areas of design as well as robotics and Human-Computer Interaction. However, its embodied and empathic potential is much less explored than the communicative and functional aspects. Kinesthetic empathy, despite its current connection to bodily performances, is a highly potential lens through which designers could start to rethink the aesthetic qualities of movements beyond utilitarianism. My exploration into the kinesthetic potential of object motions was initially difficult because of the structural gap between humans and objects. Nonetheless, by attending to the internal sensations rather than external appearance of movements, the seemingly disconnected two "bodies" began to be bridged, especially owing to the idea of kinesthetic elements. The elements identified are highly dependent on my own observation rather than objective, universal facts. Therefore, they function best when they are considered as a lens through which people can observe physical phenomena differently and build up their own observations. My ongoing PhD research has continued my observations and tested some of the elements to determine the impact they might have on designers' creative practices. These practices and kinesthetic elements grow concurrently; the change of one affects the other. The comprehensive overview of the new knowledge on this novel design approach, which I term "kinesthetic design", will be available in my upcoming doctoral thesis from the Royal College of Art.

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