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'The Human Walking Apparatus: a technological episteme'

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In March 2004, I was invited by Nouvelles de Danse editor Florence Corin to write a text that would "recall the historical development of the interactivity in the dance performance?"[1] I wrote back that "my own research takes me away from only historical artistic trajectories to look at where sciences and arts/ dance were running concurrent experiments. I am more interested to trace a certain similar view on the body that has influenced certain dance trajectories and certain machine trajectories --but not always overlapping." She accepted this proposal.

Nouvelles de Danse is a contemporary dance journal published in French by the Brussels dance association: Contredanse. Contredanse uses publications, a documentation centre, a newspaper and this site to support and stimulate choreographic creativity. Source: http://www.contredanse.org/ (accessed 7 May 2010).

[1] Email to the author, 2 Mar 2004.

The Human Walking Apparatus: a technological episteme

(This is the pre-translation English version as submitted for publication in June 2004. Illustrations in and the referencing system of the published French version are used.)

Introduction:

In his history of *Art of the Electronic Age*, Frank Popper proposes that the direct influence of technology on art begins at the end of the 19th century when the effects of the Industrial Revolution "entered everyday life… ".[1] The 1950s and 60s are considered important in the history of technology and performance arts for the shifting relations between audience and performers taking place during this period, for example in the 'Happenings', that paved the way for the new media genre of 'interactive art'.[2] The 1960s and 70s then saw the emergence of 'post-modern dance' overlapping with the early days of Computer Art, and choreographer Merce Cunningham first envisioned the computer as a creative tool; twenty years before LifeForms.[3] Clearly these were important times that have influenced contemporary practices involving emerging technologies and dance and other performance arts. But one could also look further back to discover how, for example, perceptions of bodies and movement are informed by particular technological/ scientific developments.[4]

Put another way: contemporary views on the body and movement are technological in the sense that they are informed by scientific understandings of the body as a system, seen to be functioning variously as an organ, an instrument, a sensor and a mind. This is evident in key texts that will be familiar to readers of Nouvelles de Danse such as Bonnie Bainbridge Cohen's *Sensing Feeling and Action* and Lulu Sweigard's *Human Movement Potential*; both often used in many contemporary dance practice and education settings. Cohen, with 'Body Mind Centering', and

Sweigard, with ‘Ideokinesis’, have developed singular approaches to the exercising of body and mind that foreground self-observation and awareness. Both are sometimes referred to as part of a set of techniques for mind-body training or therapy known as somatics or psychophysical education.[5] These techniques are often seen to have roots in Eastern philosophy in the ways in which they regard mind-body connections, but they are equally informed by thinking about bodies that has evolved within the context of Western philosophy and science.

This suggests the existence of an epistemology, or theory of knowledge, that affects body-based practices and renders a picture of how technology arrived in the 20th century already integrated in minds, bodies and the way movement is seen and understood; and hence has had an implicit role in the development of contemporary dance. It is not possible to fully develop this view in such a short essay; but one can begin to sketch in some of the possible details of a bigger picture. In this *technological epistemology* of the body, the machine (mechanism, apparatus or instrument) holds a central position as a metaphor for its functioning. The remainder of this essay will provide a partial exposition of the implications of this notion by focusing on a salient point in the history of movement science that should inspire us to consider the ramifications of the machine-body relation further.

(See **Illustrations** in the published French version: Thesis Page 415 from top to bottom. Top: Showing division of the gait cycle of a child by David Sutherland who established one the first motion analysis laboratories in San Diego in 1974. Bottom: A different division of the gait cycle of a child by David Winter who founded first clinical gait laboratory in Canada in 1969. Source: http://www.univie.ac.at/cga/history/modern.html)

(See **Illustrations** in the published French version: Thesis Page 417 from top to bottom. Top: Novel locomotion study tools the "glass cage" and "simplified glass cage" described by Charles Ducroquet in his book *Walking and Limping: A study of Normal and Pathological Walking*. JB Lipincott Co. 1965. Bottom: Exoskeletal goniometer examination of lower limb motions during walking at different speeds From Larry W. Lamoreux, ‘Experimental Kinematics of Human Walking’, Ph.D. Thesis, University of California at Berkeley, 1970. Source: http://www.univie.ac.at/cga/history/ww2.html)

Our fascination with how we move can be traced from Aristotle’s studies of animal locomotion around 350 BC to the modern day analysis of gait. From this classical period to the 18th century ‘Age of Enlightenment’, a handful of scientists and philosophers are credited with contributing crucial research toward the theory of human movement. This always overlapped with concurrent discoveries in other areas, but 17th and 18th century insights into the laws of physics in particular constituted a major theoretical support still significant today. Since the turn of the 20th century there has been a rapid expansion of knowledge in the field of movement studies, due in part to the invention of new instruments for recording movement. Today biomechanics and kinesiology (both referring to the study of human movement) are applied across a wide range of disciplines ranging from sports and dance science to ergonomics, biomedical engineering and occupational therapy.

But it was in the 19th century in 1836, that the Weber brothers, Wilhelm and Eduard, published their treatise *Mechanik der Menschlichen Gehwerkzeuge* (Mechanics of the Human Walking Apparatus); cited as the first “comprehensive theory of the kinematics of walking and running, based on systematic experiments”.[6] Published again in German in 1894, *Mechanik der Menschlichen Gehwerkzeuge* was translated to English in 1992, a testament to its historical importance for the field. Combining rigorous experimental methods and techniques innovative at that time, optical instruments from the collection of physics in Göttingen and experiments with cadavers from the Anatomy Institute of Leipzig, the Webers initiated the modern study of human movement. With these methodological innovations and relatively "primitive equipment" (clocks and measuring tape), they were able to infer much about the mechanics of walking. Even today's sophisticated 3-D motion capture technology has not been able to produce a "correspondingly large contribution to our knowledge of this complex phenomenon."[7]

In a review of their own treatise, Wilhelm Weber states that previous attempts to measure and analyse human movements had been "mostly unsuccessful".[8] He cites the work of the iatromathematicians, a school of Italian physicians who in the 17th century attempted to apply the laws of mechanics and mathematics to the human body. Weber writes "they stirred up hope of disclosing (…) the inside of the wonderful workshop of the human body as insight into the world's systems had been based on the brilliant discoveries of Galileo, Kepler and Newton."[9] Their failure to do so did not mean that mathematics were not useful for movement science. The Webers themselves relied on being able to calculate the forces effecting walking and running, as did others.[10] But what had been missing was a new way of looking at movement and in particular 'seeing', that which could not be seen. Having invented techniques for doing this, the Webers systematically refuted the efforts of researchers before and during their time, from Aristotle to P.N. Gerdy (who published a dissertation on the human gait in 1829) citing data collection methods that relied on *general observations* insufficient for revealing the mechanics underlying even basic movements.

The brothers' criticism of general observation are summed up in the following series of remarks,

"it is clear that the methods which have been used so far did not and will not provide clear concepts of these movements. The multiplicity and variety of movements in walking and running if all parts of the body are to be considered at the same time are too considerable to distinguish, just by looking, the essential from the non-essential (…). To attain this end one is forced to pass from simple observations to experiments. Instead of restricting oneself to looking at walking and running people in general, one must use the available means to resolve the combined phenomena into their simple components and to study these components and their interrelations. One must study the size, shape and links of the different parts. (…) Finally, one must measure time, space, masses and forces in walking itself. These experiments must be repeated many times successively to acquire the measurements, which cannot be made all at once. The experiments must vary to distinguish in these movements what is constant and what is not, and for the variables one must find the law of their dependence."[11]

The Webers determined that artists also suffered from the limitations of general observation and the inability to 'see' movement mechanics correctly. Because relations between the different parts of the body change too quickly to be "completely imprinted on the senses and in the memory instantaneously" those artists who draw and paint the human figure lack the means "directly to perceive in Nature (…) the true circumstances as they actually take place".[12] This remark in the book leads them to explaining their main discovery that had a direct bearing on artists drawing the human body; the correct inclination of the pelvis at the base of the spine. Previous investigations of anatomists and movement researchers had never, according to the Webers, revealed the extent to which the pelvis was inclined forward so as to support the lower lumbar curve of the spine; both essential to human locomotion. This inspired them to 'redraw' history by adjusting one of the illustrations of the well-known German anatomist Bernard Albinus published in the *Tabulae sceleti et musculorum corporis humani* (Tables of the skeleton and muscles of the human body) in 1749. The Webers write that their copy of the Albinus image, which tilts the pelvis forward by an angle of 21 degrees, is "aimed at showing how erroneous this picture is (…) although currently considered one of the best."[13]

(See **Illustration** in the published French version: Thesis Page 419: A copy of the original Albinus plate showing the incorrect upright position of the pelvis and diminished lumbar curve. From: *Albinus on Anatomy*. R.B. Hale, T. Coyle, Dover, New York.)

(See **Illustration** in the published French version: Thesis Page 420: The measurement of the correct positional tilt of the pelvis. From: *Mechanics of the Human Walking Apparatus*. Berlin, Heidelberg, New York: Springer-Verlag, 1992)

Albinus was well known for using a variety of measuring instruments and combining meticulous attention to detail with overlapping observations, and his illustrations were considered the "new norm eventually replacing the Vesalian images that had been the mainstay of anatomical illustration for over two hundred years."[14] It is an indication of the confidence they had in their research that the Webers could correct what was practically dogma at the time. Presumably emboldened by the extent of their discoveries, the brothers also speculated on a rather extraordinary possibility. They imagined that their discoveries might enable someone in the future to build walking machines "which will replace camels and other animals even in impracticable countries where [wheeled] vehicles cannot be used." They speculated that,

"if it can be demonstrated (…) that walking and running are such mechanical movements able to be predicted by calculation that a voluntary act of will is not needed (…) then the possibility arises of a machine, for instance moved by steam, going by itself on two, four, six or more legs."[15]

More practical was their proposal that some of their work might find an "application in the marching of troops".[16] Locomotion studies were considered particularly valuable in the eighteenth and nineteenth centuries when they were, according to historian Mary Mosher Flesher, the key to success in battle. In 1997, Flesher published an article on the relationship between 'marching theory' as developed in the context of Prussian military science and the Webers' locomotion studies.[17] She asserts that the brothers' research was oriented towards the concept of "natural self-regulation", which was different from the strict precision training the military had been using, quite successfully, with their infantry up to that point. Flesher then observes that the direction of the Webers' research began to merge with changes in military strategy in the 19th century as the emphasis in battle moved to smaller clusters of men skirmishing rather than marching en masse across the battlefield. Therefore, despite the Webers' own proclaimed "lack of knowledge" in the field of military science, according to Flesher their locomotion research was to prove important to it.[18]

(See **Illustration** in the published French version: Thesis Page 422: The zoetrope, invented in 1834 by William Horner. Source: http://www.thebigcamera.com.au/Zoetrope.html)

The above mentioned use of optical instruments to collect data for the development of their theory seems to have mainly comprised a telescope affixed with a glass scale, making it possible to survey and accurately record measurements of a person moving.[19] The Webers also provided some verification for their theories by using the zoetrope, although never referring to it as such, a new device that could produce the illusion of a moving image from a series of drawings. Invented in 1834 by William Horner, the zoetrope is considered one of many 19th century animation inventions leading up to cinema at the end of the century. The Webers write: "It is interesting to illustrate the space and time data determined absolutely according to the theory, by building and drawing the position of the limbs at each moment of walking and running regularly" and gluing the resulting series of pictures onto the "internal surface of a cylinder or of a drum".

"The length of the construction must be equal to the length of a double step. The drum is rotated at an even speed during the time of the double step. The figures are observed through slits opposite in the wall of the drum. (…) Their movements show a surprising similarity with the movements of a man actually walking or running."[20]

Forty to fifty years later, the invention of photographic techniques to capture still images in rapid succession would usher in a new phase of locomotion science. It was partly photography that made it possible for the "correction and completion" of the Webers' walking and running research by Braune and Fischer in Leipzig who published their work in a series of papers from 1895 to 1904 in the *Proceedings of the Royal Saxon Society of Sciences*.[21] Eventually these would be assembled, translated and published as a book in 1987 under the title *The Human Gait*.[22] While the Webers' *Mechanics of the Human Walking Apparatus* has a special place is the history of movement science, it is the revising of their research by Braune and Fischer that is today more scientifically significant. Just as the Webers used the latest research methods and instruments to correct the errors of their predecessors, including the redrafting of Albinus' famous skeleton; Braune and Fischer were similarly able to further unlock and reveal the secrets of locomotion, partly by using crucial tools and information the Weber brothers lacked.

Conclusion:

The *Mechanics of the Human Walking Apparatus* is one piece of evidence that our machine-body relations and the tendency to look technologically at bodies began far before the start of the 20th century. Based on an understanding of the physical forces acting on it and objectified as both mechanical and apparatus-like; the body as constituted by their research seems very close to that of their imagined walking machine. The Webers made many discoveries, some still accepted as correct, and their research remains epistemic* in the sense that it was and remains a body of ideas that determined certain knowledge at a particular time. The fact that some results have been revised by subsequent research does not diminish their impact on how moving bodies are imagined, and this imagination, the primary domain of the arts, is still under the influence of this body (of ideas) from the early 1800s.

Today, theories of movement overlap with theories of mind. Despite radical developments in the science of physics, we still live on a daily basis in Newton's world and the problem for the body of inertia and his explanation of that problem remain the same. However, the complex movement system of scrutiny today is more the brain than the levers and fulcrums comprising the mechanical body of the

Weber brothers. Researchers now model complex relations between action and perception to better understand how movement is the result of cooperation and anticipation amongst many senses.[23] Movement analysis today is accomplished with a complicated array of new instruments, hardware and software that can capture and process increasingly higher resolutions of data. As the science and culture of informatics plays a greater and greater role in helping to handle the experimental data that has resulted; the metaphor has evolved from a machine to an information body, more of an abstraction than an apparatus.

As mentioned at the start of this essay, many important histories of the relation between art, dance and technologies are to be found in the 20th century. This close, if brief, look at the *Mechanics of the Human Walking Apparatus* suggests how the technological arrived already integrated into our perception of bodies and movement; and is thus another perspective on the basis of these histories that follow.

Scott deLahunta

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(with thanks to Susan Rethorst for editing assistance)

Endnotes: (all URLs accessed as of 28 June 2004)

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1 Frank Popper. *Art of the Electronic Age*. London: Thames and Hudson, 1993. p. 10.

2 Noah Wardrip-Fruin and Nick Montfort, eds. *The New Media Reader*. Cambridge, MA: MIT Press, 2003. p. 83. "The 'Happenings' are a touchstone for nearly every discussion of new media as it relates to interactivity in art."

3 See: Scott deLahunta. 'Periodic Convergences: Dance and Computers'. In *Dance and Technology: Moving towards Media Productions* (eds. Söke Dinkla and Martina Leeker). Berlin: Alexander Verlag, 2002. pp. 66-87. Merce Cunningham. *Changes: Notes on Choreography* (ed. Frances Starr). New York: Something Else Press, 1968. no page number. "Dances can be made on computers, pictures can be punched out on them, why not a notations for dance that is immediately visual?"

4 See: Hillel Schwartz. 'Torque: The New Kinaesthetic of the 20th Century'. In *Incorporations* (*Zone*, vol. 6, eds. Sanford Kwinter and Jonathan Crary). Cambridge, MA: MIT Press, 1992. pp. 70-127.

5 Bonnie Bainbridge Cohen. *Sensing, Feeling and Action: the experiential anatomy of Body-Mind centering*. Northampton, MA: Contact Editions, 1993. Lulu Sweigard. *Human Movement Potential: Its Ideokinetic Facilitation*. New York: Harper & Row, 1974 There are many websites with somatics content. For one that discusses somatics in the context of western medicine see: Jeffrey Ives and Jacob Sosnoff. 'Beyond the Mind-Body Exercise Hype'. in The Physician and Sportsmedicine. vol. 28: no. 3, March 2000. URL: http://www.physsportsmed.com/issues/2000/03_00/ives.htm

6 Paul Maquet. In the 'Translators Preface'. Wilhem Weber and Eduard Weber. *Mechanics of the Human Walking Apparatus*. Berlin, Heidelberg, New York: Springer-Verlag, 1992. [*Mechanik der*

Menschlichen Gehwerkzeuge. Dieterisch'sche Buchhandlung,1836; Berlin: Verlag von Julius Springer, 1894)].
7 Aurelio Cappozzo and John P. Paul. 'Instrumental Observation of Human Movement: Historical Development'. In *Three-dimensional Analysis of Human Locomotion*. P. Allard, A. Cappozzo, A. Lundberg and C. Vaughan, eds. New York: John Wiley & Sons, 1997. p. 7.
8 Wilhem Weber and Eduard Weber. *Mechanics of the Human Walking Apparatus*. Berlin, Heidelberg, New York: Springer-Verlag, 1992. p. 226.
9 Ibid.
10 One later example was in the 1930s when Russian physiologist Nikolai Bernstein developed the first differential equations to describe motor function in his research into movement coordination. For an interesting discourse on this in relation to the evolution of Rudolf Laban's work see: Hans-Christian von Herrmann. 'Movement Notation: An Examination of Rudolf von Laban's Kinetography around 1930 in the Context of the History of Science and Media History'. In *Dance and Technology: Moving towards Media Productions* (eds. Söke Dinkla and Martina Leeker). Berlin: Alexander Verlag, 2002. pp. 134-161.
11 Weber and Weber. p. 216.
12 Ibid. p. 3.
13 Ibid. p. 222.
14 See: Fisher Rare Book Library, Digital Collections, University of Toronto. 'A Brief History of Anatomical Illustration'. In *Anatomia 1522-1867*. http://digital.library.utoronto.ca/anatomia/ and http://eir.library.utoronto.ca/anatomical_plates/application/history_illustration.cfm
15 Weber and Weber. pp. 1-2.
16 Ibid. p. 4.
17 Mary Mosher Fletcher. 'Repetitive Order and the Human Walking Apparatus: Prussian Military Science versus the Webers' Locomotion Research'. In Annals of Science. September 54(5), 1997. pp. 463-487.
18 Weber and Weber. Foreword. p. VIII.
19 Cappozzo and Paul. p. 4.
20 Weber and Weber. p. 218.
21 Paul Maquet. In the 'Translators Preface'. Wilhem Weber and Eduard Weber. *Mechanics of the Human Walking Apparatus*. Berlin, Heidelberg, New York: Springer-Verlag, 1992.
22 Wilhelm Braune and Otto Fischer. *The Human Gait*. Translated from the original German papers (1895-1904) by P. Maquet and R. Furlong. Berlin, Heidelberg, New York: Springer-Verlag, 1987.
23 See: Alain Berthoz. *The Brain's Sense of Movement*. Cambridge, MA: Harvard University Press, 2000.