

Force Field: Vitruvian Man and the Physics of Sensory Perception

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Abstract: Leonardo Da Vinci's Vitruvian Man, a diagrammatical design of the human form in relation to its geometrical proportions, is one of the most enduring images of the European Renaissance. Vitruvian Man provides a key to the proportions of Vitruvius's architectural drawings contained in his Ten Books on Architecture, *De Architectura*. (The description of Vitruvian Man is formed from Book Three in particular). Completed in 1490, it was fashioned after drawings of the Roman architect/engineer Vitruvius who lived in 1BCE. Da Vinci sought to portray the symmetry of human form as both measurer and agent of civilisation. Da Vinci placed his diagrammatical interpretations of Vitruvius's writings inside a square and overlaid this with a circle representing a secular design of the human form in three-dimensional space. However, Vitruvian Man depicts not only a relationship of geometrical proportion but also a human 'performance model'. Whether Leonardo thought that the mathematical delineations pointed to an underlying implicate order, he did not directly write on the subject. Vitruvian Man represents the dividing moment between the natural world and the world of modern civil engineering and the human architectural environment. It is a founding document for the evolution of the Newtonian age and the recognition of humankind as the centre of civilisation.

Key words: Vitruvius, Da Vinci, Physics, Architecture

Introduction

Vitruvian Man represents the human being in proportions of the geometrical physical form. Current advances in the measurement and description of the physics of the body (stemming from successive adaptations to the nineteenth century science of psycho-perception) lend themselves to the enhancement of Da Vinci's diagram. If Da Vinci's diagram seeks to represent the harmony and proportion of the physical body, the sphere of proportion surrounding the figure of the Vitruvian Man can be adapted as a model of human experience to include the physics of sensory perception. Through its representation of the agentic form, Da Vinci's diagram also acknowledges of the dimensions in which the human lives and breaths - the physics of environmental perception.

This positioning of the agentic human within the phenomenological world is entirely in keeping with the philosophy of Renaissance humanism. Extending Da Vinci's two dimensional representations into three dimensions – to effectively place Vitruvian Man in a sensorial sphere – the proportions of the circle, need only be completed as lines of longitudinal radii. If Da Vinci were to modify his diagram for the 21st Century it seems natural that he might have sought to take into account the environment in which the human being senses function. Da Vinci's diagram lends itself to the innate measurement of sense perception of the environment that is an intrinsic part of human inhabitancy.

State of the Art

Marcus Vitruvius Pollio wrote in the first century BC during the reign of Emperor Augustus, the first Roman emperor (63BC-14AD). Beginning his career as a military engineer, Vitruvius was the first Roman architect to leave surviving written records of his studies. The architectural drawings contained in his Ten Books on Architecture, *De Architectura* describe essential principles of architecture, town planning, construction and design.

Book Three of *De Architectura* also revealed a deeper purpose so far as Vitruvius sought to represent a key for the representation of human proportion in architectural design, perhaps the original mathematical statement of logocentrism in architectural theory. Vitruvius writings became, in the fifteenth century, written instruction for Leonardo Da Vinci's (1452-1519) rendering which embodied the Renaissance ideal of 'l'uomo universale' (the Universal Man). In the nearness which the perceiver feels to the universal 'other' of history upon viewing Da Vinci's diagram, there is a subjective quality described as *illeity*. This is the perception of a third-person-ness which is inaccessible, which can never be present (and which perhaps never was present) but which Da Vinci's diagram alludes to in perpetuity. In this reading Vitruvian Man is an interlocutor. If Da Vinci represents an eternal design of fundamental human proportions, then the Vitruvian Man is a form of irruption not only in the "realm of presence . . . but rather a breaking up of the way [the] mind relates to the world and everyone in it." (Gibbs, 2000, 32). Vitruvian Man denotes the tension between the 'saying and the said, the doing and the done': between the content and the activity of human signification. In portraying a moving human form within a geometric matrix, Vitruvian Man is agentic and performative. Both active and passive states are portrayed in the text describing the diagram of Vitruvian Man. Leonardo wrote:

Vituvius, the architect, states in his work on architecture that the measurements of a man are arranged by Nature thus:--that is that four fingers make one palm, and four palms make one foot, six palms make one cubit, four cubits make once a man's height, and four cubits make a pace, and twenty four palms make a man's height, and these measurements are in his buildings.

If you set your legs so far apart as to take a fourteenth part from your height, and you open and raise your arms until you touch the line of the crown of the head with your middle fingers, you must know that the centre of the circle formed by the extremities of the out-stretched limbs will be the naval, and the space between the legs will form an equilateral triangle.

The span of a man's outstretched arms is equal to his height.

From the beginning of the hair to the end of the bottom of the chin is the tenth part of a man's height; from the bottom of the chin to the crown of the head is the eighth of the man's height; from the top of the breast to the crown of the head is the sixth of the man; from the top of the breast to where the hair commences is the seventh part of the whole man; from the nipples to the crown of the head is a fourth part of the man. The maximum width of the shoulders is in itself the

fourth part of man; from the elbow to the end of the shoulder is the eighth part. The complete hand will be the tenth part. The genitals begin at the centre of man. The foot is the seventh part of the man. From the sole of the foot to just below the knee is the fourth part of man. From below the knee to the genitals begin is the fourth part of man. (Da Vinci, 1517/2003, 213-214)

Da Vinci's reiteration of Vitruvius's writings challenges the tendency of language to suppress the possibilities of humankind within the familiar aspect of the 'presentable'. The text is an expose or profanation of the possibilities of a signifying, transcendent human. However, as Larsen observes, in his drawing Da Vinci makes use of the fact that "Vitruvius only mentions that the centre of the circle should be in the naval, but does not spell out clearly the bodily position of the point of intersection of the diagonals and the square" (2005,57). Consequently rather than interpret human form, circle and square as static geometrical figures, Da Vinci portrays them as "two interdependent forms united through the body and its movements, not two completely synthesized cosmic forms" (Larsen, 2005, 57). Larsen therefore concludes that Da Vinci's geometry is secular, portrays a 'self-confident subject', and locates order within a body. This body represents 'ideal proportions' but also is an agent who sets them into motion (2005, 58).

Vitruvian Man marks an important turning point in the description of the secular age of the eotechnic era and the recognition of humankind as the centre of civilisation. Indeed Da Vinci's rendering of Vitruvius's textual form is an inscription of Renaissance logocentrism. The text is alive with traces, if not of divine instruction then of the authority of transcendent design.

Conceptually we can see that Da Vinci's drawing is a *cosmografia del minor mondo* (cosmography in the microcosm). Renaissance semiologists have interpreted the basic geometry of Da Vinci's drawing in terms of two aspects: the 'material' existence symbolized by square, and 'spiritual quality' by the circle. In the circumference of the circle in which the human body is in motion we can infer that Da Vinci implied a greater frame of reference for his representation than that of physical proportion in two dimensions. The radii of its circumference is an inference of the 'perceptual sphere' in which mankind is constituted. In the diagram below, Vitruvian Man is constituted in this environment or 'force-field' in which his sensory functioning operates – the psychophysics of sensory perception.

As a humanist, Da Vinci's investigations did not foreclose a world entirely defined by religious thinking. He was a 'physical scientist', his investigations of the material world and the place of the 'creation and inventions' of humankind within it, were motivated by empirical causes. Through his anatomical drawings in motion and at rest it is evident that he sought to understand how mankind functioned physically, as well as how the human could be applied to the architectural environment. Da Vinci located his sense of the spiritual in the creation of a logos in which the human is arbiter and agent. This tendency towards logocentrism implied a greater agency for humankind in the processes of invention and creation than in conventional religious belief. Through the body form depicted in motion in the circle and the square he sought a link that would relate the capacity of humankind to explore the orders of the world by exploring the relationship between the human form and the human environment. But if the circle represents the 'spiritual' it also represents the sphere of human influence, a sphere of

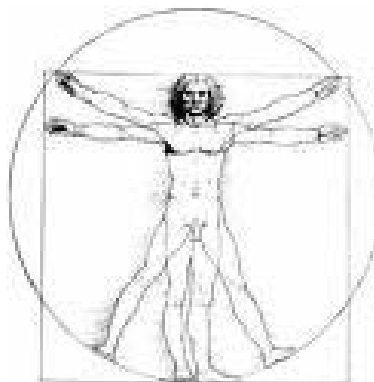
The human body: stimuli/sense thresholds

Psychoperception	N	Stimulus
brightness	0033, 0.5	5% target, point source – dark adapted eye
loudness	0.54, 0.60	Monoaural, binaural
smell	0.55, 0.60	Coffee odor, heptane
vibration	0.6, 0.95	250Hz, 60Hz – on finger
taste	0.8, 1.3, 1.3	Saccharine, sucrose, salt
temperature	1.0, 1.6	Cold, warm – on arm
Pressure on palm	1.1	Static force on skin
heaviness	1.45	Lifted weights
Electric shock	3.5	60 Hz through fingers

Fig 1. Table adapted from Irving Herman. (2008). *Physics of the Human body*. Springer: New York. Pp. 25-26.

Electromagnetic:
Vision: 390nm < N
<720nm

Thermal -
Cold/Warmth:
Body temp: 91.4.
Skin temperature
98.6. Thermal
adaptation between
55 and 110 degree
Fahrenheit.



Chemical:
Taste: 30–140
mg/L Sodium
and 340–680
mg/L, Potassium
Smell: Minimum
 4×10^{-7} molar
concentration of
quinine sulphate.

Mechanical:
Hearing: 20Hz to
about 20 KHz.
Touch: 3Hz-500Hz

phenomenality. Through an ability to manipulate technology and material existence (a proportionality of a perceptual sphere), the diagram 'speaks' of the possibilities of humankind.

As Roth suggests, the circle also symbolised the 'perfection of the deity' (1994, 321). The circle is thus a representation not of enclosure but of infinity. It represents the break between the physical and the non-physical, extending Vitruvius's notion of proportionality beyond material physicality. It is thus a rendering of the transcendence of the fourth dimension – time (the circle representing infinity) as well as the human form in immersive environmental suspension. Da Vinci's diagram is a 'load-bearing' structure, as well as an organism conceived of in divine proportion. The use of the 'cubit' in Da Vinci's interpretation of Vitruvius's writings was a geometrical measurement of area and volume. The extension of the possibilities of human anatomical-functioning draws upon the human capacity to 'realise' the environment in an objective agency. The functionality of Vitruvian Man is in keeping with Da Vinci's purpose as a 'physical scientist'. If we examine the measurements of sensorial perception in the preceding diagram, we notice that the relationship of the figures also conform to Vitruvius's sense of proportion. The fundamental constant derived from these is that human sensory perception experiences a range of three orders of magnitude expressed in Newtons.

In order to justify this interpretation we must look to Vitruvius and Da Vinci's influences, to the Greek Platonic and Pythagorean foundations of the architectural implicate order. Within the context of Vitruvius's classical orders of architecture, the Vituvian man was an anthropomorphic symbol that did not negate the natural world but rather provided a bridge between it and the world of *homo faber* (man the maker). It was a key by which to measure, and explain buildings fashioned after principles of a divine aesthetic. This aesthetic was achieved through a careful analysis of proportion, connection and harmony of constituent parts. It was not enough that human proportion would be the 'primer' for architectural constructions but that through the senses mankind could discern an implicate order of transcending anthropomorphic value. Analysis of the human form through architecture was another way of approaching the spiritual through the notion of a transcend ideal based on anthropocentric proportions: a golden section.

Thus renaissance authority was derived from humanist principles. In both Vitruvius's and Da Vinci writings, Vitruvian Man, is a key for proportionally of design. However, while they may have written *with* a body neither Vitruvius nor Da Vinci wrote *onto* the body. Vitruvian Man was not a surface-text but a symbol of the transcending value, a logocentric object. Da Vinci demonstrated that geometrical analysis implied a situatedness in which Vitruvian Man has *a priori* an agentic purpose.

That Vitruvian man is a figure bridging ancient and future worlds is supported by the French social theoretician, Michel Foucault who elides postmodern reflections on Vitruvius's architectural theory with considerations of urban living, private architecture, collective facilities and hygiene. Vitruvian architecture was a plan for living in the Roman republic which sought to partition a building according to the functions of the human body. However, Foucault emphasises the point that architects of the fifteenth century were forward orientated humanists. Consideration of the human form is developed by the modern influences in the eighteenth century into the reified thought of the civic sphere (Foucault cited in Leach, 1977, 68).

In contrast, as Gelernter points out, the fifteenth century revival of the ideas of Vitruvius involved an 'utmost reverence' (1995, 61). Although Vitruvius based his architectural concepts on a Greek sense of the physical world, this could not be described as a secular materialism apart from as an architectural ideal. Rather the designs of architecture were based on transcendent principles of timeless universal validity and beauty. Renaissance humanism interpreted this in the light of a blend of Platonism and Christian spiritualism. As Gelernter suggests, the 'problem' which Da Vinci sought to portray (which preoccupied the Renaissance humanists as much if not more than the classicist whose ideas they sought to interpret) was, that of: "if one turns away from divine sources of knowledge or art and looks instead to the sensory, physical world, how can one find any timeless principles in a world which continually comes into being and passes away?" (Gelernter, 1995, 62) Vitruvius extended Greek principles in so much as he added to his elements of practical design an aesthetic refinement that involved new ideas of subjectivity. This is a refinement of the senses towards an objectivity that would inspire a 'delicacy of feeling'. Thus, Vitruvian Man was a centrepiece that confounded the objective Pythagorean principles of the 'golden mean' in so much as it described that the human form in relation to the geometry that gave them expression. The creator of architecture was itself an architectural form. Moreover, it was an acknowledgement of duality, the human engineer was also an object of engineering, the 'deeper anthropocentric' paradox being that the Pythagorean form requires 'subjective feeling' in order to appreciate the view of objectivity. Furthermore proportional form describes architectural ideals which promote a positive subjectivity. How is this possible?

Before attempting to answer this it is necessary to point out that Gelernter also identifies a further conundrum in Vitruvius exposition of a theory of architecture deriving from the 'truth of nature'. The Greek theory of idealism contains a tautology: If the classical architects designed and built by testing their experiments against the truth of nature (rejecting failures, retaining successes until form was refined), then by exploiting principles of both functionality and transcendence they must therefore 'know' the truth of nature, and not have to experiment to find it (2005, 62).

Da Vinci may have meant to represent Vitruvian Man as a solution to this conundrum. In this reading, Vitruvian Man is the key, the primer to the 'truth of nature'. If proportionality is contained mathematically within the human form, the human mind needs only to regard the human form objectively to find the formula of proportions which will preserve its ideal subjective agency. As Larsen states, "Leonardo's body is both a genuine part, matter and form . . . of the human life-world it refers to, and a condensed sign of it as created by Man according to principles of human form" (2005, 58).

Thus the human body contained an analogue of the golden section. Consequently, Vitruvius had discovered certain unvarying proportions: that the 'ideal' human body can fit within a circle drawn from the naval, and within a square touching feet, outstretched hand and the head. These fundamental proportions were recommended as principles of nature to architects. However, as Larsen points out, Giambattista Vico in *New Science* (1744) distinguished between the autonomous dimensions of human life – "the world of civil society . . . made and known by mankind" – and nature which he believed "only God who created can understand" (Giambattista Vico cited in Larsen, 2005, 58).

Gelernter further points out the difference between positivist and logocentric architectures. In the former, the architectural site, climate and building function, create the architectural form. However, in Vitruvius's logocentric theory, these only "adjust to a form that has been created by manipulation of a geometrical system based on the proportionality of mankind" (2005, 63). Thus there is a fundamental bifurcation between the human in a state of nature and 'homo faber', who carries around the proportions of his or her environment in his or her own objective being. The subjective mind is contained within a system, it is a 'form within a form', giving rise to the problem that 'the eye does not always give a true impression, but very often leads the mind to form a false judgment (2005, 65). This was a principle of the convex nature of sight which Da Vinci understood (Da Vinci recognised that the eye takes in but doesn't send forth anything from itself, except to the brain - for "the eye is in itself completely dark" (1517/2003, 242)).

Adaptation of form requires reflection and invention, the use of mechanical rules and intuitive judgment and sense of correctness when accommodating the conflicting requirements of form. However, it is not quite the case as Gelernter suggests that, Vitruvius gives no account of how these subjective, inventive skills are reconciled with design based upon objective and timeless properties of nature (2005,65). Rather, Vitruvian Man represents both this problem and the possibility of its solution. Vitruvian Man posits the problem in perpetuity, at the same time representing the potential for its solution through a careful balance of the material and the spiritual, the symmetry of subjective intuition and objective purpose. The architect satisfies the criteria of 'commodity, firmness, delight' by first establishing a 'standard geometric model' from which he can derive the dimensions and proportions of architectural practice (2005, 63).

Alberti was convinced that "the very same numbers that cause sounds to have concinnitas, pleasing to the ears, can also fill the eyes and mind with wondrous delight." (Alberti cited in Roth, 1994, 322). This was contained in the Pythagorean musical theory of 'consonance' in which contemplation of relations of architectural parts may be harmonious. Thus the 'theory of orders' was associated with a complete system of architectural measurement, expressed in precise mathematical relationships from which form is resonate and implied rather than 'stated'. This was believed to be *la ragione delle cose*, the 'causality of things' (derived from mathematical principles such as the golden section rectangle which exhibits the ratio $(1+\sqrt{5}): 2$) (Scruton, 1979, 62). However, these 'reasons' so stated are themselves independent of aesthetics. One cannot derive a principle of harmony from mathematics alone. A mathematical formula is a symbolic representation independent of the human mind that created it. As Scruton points out, it is, at best, a 'hidden' cause (1979, 62). Unlike Da Vinci's Vitruvian Man, the system of proportion does not itself say what proportion means. Scruton suggests that the rules of proportion are *a posteriore*, and do not derive from the meaning of the term, but from a discovered relationship of its parts, and particular points of view that are extrinsic to its statement (1979, 66). This concept is further reinforced by the representation of the golden section (*sectio aurea*) - an irrational mathematical constant (1.6180339887) - in Vitruvian Man.

According to Scruton, there were five separate Vitruvian standards: regola (rules), ordine (orders), misura (measurement), disegno (design) and maniera (manners) (1979, 59). The notion of a 'harmonious order' derived from rules and principles of proportion was also believed to be related to music - hence the Twentieth Century modernist architect Le Corbusier's claim that architecture is 'frozen music'. Le Corbusier's architectural system was an extension of Leonardo's suggestion of the golden ratio in human proportions using Fibonacci numbers (Seed value $F_0=0$ and $F_1=1$, $F_n=F_{n-1} + F_{n-2}$). Le Corbusier divided the model human body's height into two sections in the golden ratio from the navel and divided further into the golden ratio at the throat and knees. These were then adapted into a modular system by Le Corbusier.

Furthermore analysis of proportion the 'golden mean' through architectural form was believed to be able to conquer destructive urges partially through the demonstration of different levels of intentionality in consciousness. Vitruvian Man was primarily a 'self-conscious' act, and secondly provided proportioned form that inspired cultural preservation. Not only was Vitruvius's architecture functional, and from an anthropomorphic principle, itself the expression of a quotient of 'ideal' value but it was also a metaphysical statement. As Schulz points out, the correspondent belief was held during the Quattrocento that through the expression of transcendental laws of nature in architecture, science and arts, humankind would gain the ability to overcome 'the dark side of existence'. This revelation that the renaissance humanistic preoccupation with proportion was psychologically motivated, is illumined by Alberti, who wrote: "Beauty will have such an effect even upon an enraged enemy, that it will disarm his anger, and prevent him from offering it any injury . . . that there can be no greater security to any work against violence and injury, than beauty and dignity" (Alberti cited in Norberg-Schulz, 1975, 254).

Da Vinci's Vituvian Man is then a representation of human design through structural and environmental relationships implicit in proportional form. Neither fully hiding nor disclosing it leaves traces of a logocentrism which transcends the knower but which also conveys an agentic responsibility to the viewer. Extending the diagram into three dimensions to include the physics of sensory perception preserves the order of the relationship of proportionality.

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