Embodiment in haptic architectural diagrams

Esen Gökçe Özdamar

DOI: https://doi.org/10.20868/cpa.2023.13.5176

Introduction: architectural diagrams

Historically, architects have used technical drawings to represent their architectural ideas, not only to refine their thoughts but also to convey their ideas to others[1]. Architectural drawings and representations, whether technical or surreal, have enabled designers to enrich their design thinking, processes, and products, and have enabled architects to experiment, reflect, and scrutinize their ideas. Architectural design thinking is a complex process that is primarily shaped in the mind of the designer and simultaneously rendered by a complex milieu, comprising the problem context, limitations, expectations, program, content, users or participants, and the moment in time. It is within this context that architects express themselves freely and openly and generate their ideas. In this complex design context, the designer uses their physical body to varying degrees in sketching, modeling, prototyping, diagramming, and animating. From sketches and scribbles to model making, from digital design to 3D immersive environments, designers communicate through the environments they are embedded in. With the widespread use of computer technologies, designers use tactile paper and pen far less than before, and instead use digital screens, mixed reality, 3D printers, or 3D pens.

Drawings are tools of translation between design and building[2]. They have several typical traits. They are "evocative" in that they convey the experiential qualities of the design, or are "instructional" in that they may be "notational drawings" which convey precise dimensional and material information[3]. Among architectural representations, diagrams[4] are "imaginative devices" which convey "powerful metaphors."[5] They can be figurative or non-figurative representations and can contain quantitative and qualitative information that can be transformed into physical designs, or which can convey intense visual information relating to tone, context, and a myriad of other ideas. Diagrams convey and refine information in the design process, capturing measured and geometric data, and guiding the creative processes[6]. They enable designers to explore the potentialities of design elements such as form, space, materiality, scale, light, and use[7]. As Andrew Chaplin argues, in the design process a diagram is "a visual language—a medium between thoughts and reality."[8] Diagrams clarify relational knowledge, elements of the design, the process of construction9, and the spatial relations in an architectural problem[10]. They depict real world objects and the spatial relationships between[11] them. In his book Space is the Machine, Bill Hillier argues that architectural diagrams are more than just a representation[12] and "the designer is in effect a configurational thinker."[13] He argues that "the idea of architecture is at once a thing and an activity, certain attributes of buildings and a certain way of arriving at them" in which product and process are not independent of each other.[14] Product and process converge in Hiller's work. An architectural diagram serves both as "an activity" and as representation of the designer's intent in itself and as an "interchangeable artifact."[15] Therefore, a diagram can embody both the relationship between physical form and spatial form and the relationship between "bodily function and socio-cultural function."[16]

In the design process, architects produce diagrams for two primary purposes. The first is to design "more pictorially" to "record[...] the preconceived idea of the building."[17] The second and more important purpose is to draw and "interact with their diagrams" in order to design spatially.[18] To design pictorially refers to a representative and descriptive process, while the latter refers to the embeddedness of the designer in the space of the design problem and context. The second purpose offers a more effective and internalized approach due to its physicality. According to Riahi, diagrams, as well as other sorts of drawings and representations reveal the creative process[19]. Diagrams, on the other hand, not only demonstrate ingenuity, but also generate visual, kinesthetic, and tactile effects in their process of creation, which can orient the designer.

There are different classifications of architectural diagrams used by designers. Fraser Shields sees diagrams as a tool for architects and speaks of their "open" and "generative" nature as they free the process from "formal considerations.",[20, 21] Analysis, datascape, organizational, operational, conceptual, and abstract diagrams are some examples of this type.,[22, 23] Depending on the environment in which they are produced, architectural diagrams can be conventional, digital, or hybrid. Conventional environments involve tools and media such as drawing, collage, and assemblage and can involve the traditional use of ink and paint on surfaces such as parchment, tracing paper, mylar, cardboard, glass, metal, wood, and fabric. An example of this type of diagram is Guy Debord's map of Paris (Guide Pychogéographique de Paris, 1957), which is a mapping of the fragmented city, discovering new ways of moving through the city, drifting, and thinking about places in which the spatiality of difference emerges as a tactic for re-reading the relationship between experience and the built environment[24]. More mathematical or cinematographic diagrams include Christopher Alexander's organization charts, Lebbeus Woods' surreal works, Bernard Tschumi and Peter Eisenman's montage works, and Zaha Hadid, Rem Koolhaas, and UNStudio's generative diagrams made for productive processes.,[25, 26] By contrast, some diagrams are built during the design process and bring complex data together to find emerging parameters. These diagrams include sensory maps, network maps, and data that grows or transforms through immersive environments.

However, many diagrams are realized in two-dimensional media and are not haptic or have less tactile traits. Modernist examples of haptic diagrams and experiments are mentioned in Henri Focillon's *In Praise of Hands*[27] and include the influence of haptic education in Montessori,[28] haptic collages of the Dada movement, Le Corbusier's formal investigations with transparent cellophane sheets of superposing Zip-a-tone patterns in *The Modulor II,*[29] Bauhaus corporeality and anthropomorphic diagrams, Sol LeWitt's 3D diagrammatic installations, and Alvar Aalto's phenomenological haptic wood reliefs. In the 1960s and 1970s, handcrafted visualization tools were widely used in experimental representations in fanzines and in the works of Archigram.

Haptic diagrams can enhance the process and approach of the designer to challenges in design methodology. Therefore, this article investigates how haptic diagrams can improve the efficiency and embodiment of the design process by embedding the designer's experience in the design problem.

Diagrams can be essential to both the production and acquisition of knowledge as they might allow the designer to discern possible ideas. Diagrams incorporate the perceptions of the designer and the audience, incorporate operational norms, and may make it easier to unravel the mysteries which these contain.[30] The study of haptic diagrams in this article is limited to postmodern practices. Many contemporary works of art are characterized by "appropriation, site specificity, impermanence, accumulation, discursivity, [and] hybridization," distinguishing them from their modernist forebears.[31] As Owen argues, allegorical imagery is appropriated imagery. In these contemporary works, the allegorist does not create images, rather, they seize them. In their hands, the image changes into something else. Allegory is related to the "fragmentary, the imperfect, the incomplete," and "affirms its own arbitrariness and contingency."[32] In these works, designers generate images through the reproduction of images.

Hapticity in architectural diagrams

Haptic diagrams are spatial models or representations that demonstrate the concept underlying them by stimulating a sense of touch and bodily connection beyond visual sensory data. They can also be thought of as layered or fractured juxtapositions of diverse parts that are sensorily tactile due to the material and textural properties of the surface on which a diagram or drawing is rendered, and are a layered or fragmented juxtaposition of various elements. A diagram's tactility is enhanced by its thickness, depth, and fragmentary juxtapositions.

The haptic relates to one's sense of touch or to tactile sensations. According to Papale et al., "Touch is constrained both spatially and temporally, as compared to vision."[33] As Pallasmaa argues that it affords an important role for tactile-based perception and imagery in the architectural experience. Tactility can emotionally integrate inanimate objects and can provide a sense of presence (referring to the perception of immersion in the surrounding environment) whereas vision usually does not do this. Pallasmaa's sensorial integration or involvement through bodily perception occurs through direct contact with the perceived object. Contact is primarily heightened through properties such as surface texture, shape, or position in space.[34] In his book, The Thinking Hand, he argues that during sketching, the designer's hand is engaged in a "direct and delicate collaboration and interplay with mental imagery," and it is impossible to know whether the internal mental image or the sketch appears first.[35] The initial mental image can emerge as a visual entity, but it can also be a "tactile, muscular, or bodily impression, or shapeless feeling that the hand concretizes."[36] Therefore, haptic perception can emerge through the interplay of the designer's imagination and hands.[37]

Evans argues that there are two opposing conditions in representation: one regarding the corporeality of the things made and the disembodied properties in the drawing. He describes these as "involvement, substantiality, tangibility, presence, immediacy, direct action" and "disengagement, obliqueness, abstraction, mediation and action at a distance," respectively.[38] Tactility has been found to be the closest to vision in terms of semantic and cognitive processing of pictorial information.[39] However, the haptic effect of an architectural diagram brings forth a puzzle-like integration to the process, arousing curiosity and the desire to discover and understand the reality or realities it evokes. Diagrams can be interacted with based on their haptic features. Linear elements such as rope, wire, or surfaces (such as metal and wood), can increase contact with the material. Secondly, diagrams containing illusion-like or angled geometries can increase woven contact and can evoke the urge to understand and explore. Third, in the context of Arnheim's concepts of distortion and deformation, differently perceived formal qualities such as obliqueness, the axonometric effect, depth effect surfaces, or gravity[40] can enhance the effect of touch. As Arnheim argues, visual experience is not limited to a single object—it can also arise when moving around in an environment and seeing objects from different viewpoints. Viewers can move around an object, or an object can turn in front of the viewer's eyes, resulting in changing projections from the perspective of the viewer.[41]

An example of an earlier haptic architectural diagram is volvelles (from the Latin word volvere: to spin), known as the rotating paper mechanisms that were mounted inside manuscripts of Arab scholars from the 12th century. Although the books written in this period were in fields such as astronomy, clockwork, and astrology, these diagrams began to be seen in the fields of geography and medicine in the Western world and partly in architecture. Such an example can be found in Vitruvius' Ten Books on Architecture, Barbaro edition (1556)[42] [Fig. 01]. Folding sheets, volvelles, and other moving book features invited the viewer into a tactile engagement with the book, as the pages became spaces for exploration.[43] They not only provided knowledge or control of the knowledge to be discovered, but also provided a sense of sensory integrity and a sense of embodiment through a kind of being-in-knowledge.

Linearity and fragmentation in the enhancement of visual acuity in architectural diagrams

According to psychologist James J. Gibson's (1950) studies, the sensations of space are assumed to be the impressions of surface and edge.[45] According to the pioneers of Gestalt psychology, Katz and Koffka, one of the key aspects of perception of a determinate surface is visual resistance in relation to texture and visual acuity. This means that the property of a "surface is that it is solid to vision as well as to touch," as well as the qualities of extended color, being illuminated or darkened (i.e., lighted or shadowed), the quality of slant, the property of nearness or farness, the impression of a closed contour, the quality of shape at a given slant, and the quality of size at a given distance.[46]

Sketching becomes a form of exploration in Lebbeus Woods' Terrain (1999) project, which contains speculative excursions from the present architectural output and explores new types of space. Woods created dynamic forms in response to swift changes in modern urban cultures and environments.[47] Similarly, Chris Kenny's three-dimensional collages of map fragments initiate a design process, creating cartographic abstractions as conceptual word clouds [Fig. 02].

Linear or fragmentary pieces in a defined surface (such as wire or string) can provide a stimulus to provoke touch and may even elicit qualities such as elasticity or the production of sound through vibration when touched. Architectural diagrams that are between abstract representations and consist of linearly oriented materials or patterns can provide a sense of touch for the designer. They can elicit the idea and action of an unfinished design intervention that is open and productive to the design process and product. Kate McLean's sensory 'smellscape' mappings, Ben Spong's models [Fig. 03], and Takatsugu Kuriyama's model of Tokyo's complex subway system are a few examples of this kind of diagram.

Sarah Sze's 3D works alter the scale between microscopic observation and the macroscopic vision of infinity by combining gathered objects and photographs from both the physical and digital worlds in complex multimedia pieces. Sze's work is dynamic and productive, encompassing sculpture, painting, drawing, printmaking, video, and installation with 3D materials related to entropy and temporality.[50] The combination of collage with axonometric representations is intriguing, as is Daniel Libeskind's transformation of handcrafted collages into three-dimensional shapes, and the haptic installations of artist Katsumi Hayakawa [Fig. 04]. Another example by SANAA demonstrates how an Euclidean layout of the Glass Pavilion at the Toledo Museum of Art can be transformed into a haptic representation and how diagrams act as catalysts for reimagining space [Fig. 05].

Complexity and transparency in the enhancement of visual acuity in architectural diagrams

The layering, fracturing, or transparency of the elements of architectural diagrams can result in the perceiver moving to process the data physically. These diagrams create a sense of playfulness, intervention, exploration, and bodily interaction between the designer and the environment. The intricate structure of architectural diagrams, as well as the transparency and traceability of physical media such as paper and acetate or digital media, are helpful in creating layered and tacit knowledge. Transparency and the superposition of shapes, is heightened by shape relations and their lightness.[53] The tracing paper and the medium used to draw or transfer diagrams have similar effects. Tracing allows designers to combine diverse elements into a composition using cinematic techniques like montage.[54] As stated by Olcott Price, tracing paper is used in the drawing[55] process, and in the reading of drawings. Tracing is a type of knowledge production in architecture that has shown remarkable persistence in the face of significant changes in dominant modes of architectural production. It allows for both copying and innovation through line selection and omission, variety, and invention. The layering of materials such as paper or other media introduces a plurality and a layering that can be manipulated, rearranged, animated, and repositioned to create variation or unity in the design thinking process. In tracing paper representations, there are "continuities and discontinuities, flows and abrupt halting," which include "a depth and thickness."[56] This understanding of tracing is reminiscent of Gibson's (1986: 22) ideas on the distinction between "medium, substances, surfaces.",[57, 58]

In these diagrams, the tactile features become more visible, or this effect may be achieved by digital manipulation, creating the effect of depth. Shaun Murray's ENIAtype diagrams can be given as an example of a transdisciplinary reading methodology. Murray proposes a notational system for the relationship of context, design, and communication. Based on the 26-rule and a contextualism-based notation system, Murray's diagrams draw inspiration from Gregory Bateson's recursive vision. Murray demonstrates the interconnections between the environment and human behavior that translate into space in this system. The notation sets and drawings initiate a dialogue that reveals potential interactions and existing environmental conditions. "Affective touch" (no. 21) and "tactile insertions" (no. 22) are two of these rules.[59] He conveys

shamanistic intensities of creativity as well as empirical and scientific registers of diagramming in his other exploratory mapping, Mirror Curtain (2021). He methodically manages and embodies the material while claiming bodily independence from such constraints.[60]

Many analog architectural collages are haptic due to their partial transference, transparency, and material layering, which foster haptic interaction, evoke a visceral response, and suggest several interpretations. Many designers believe that "tangible qualities of space and form are heightened and revealed" through the creation of collages, and that the collage enriches the perception of the spatial and material experience of the architecture[61] [Fig. 06].

In the above Figure 6, the diagrams are multi-layered cut-out drawings printed on tracing paper and acetate and are re-readings of contemporary urban residential spaces in Istanbul, Vienna, and Amsterdam. They are ontological, epistemological, and logic of the middle axioms, and are derived from the transdisciplinary methodology of Basarab Nicolescu.[63] The superimposed layers depict the temporal span of the re-reading process, merging fragments of urban dynamics such as speed and flexibility, as well as an installation art project and in-depth interviews with various participant groups. Transparency in the superimposed layers, as described by Rowe and Robert Slutzky, displays implicit knowledge and tangible properties in the signified system. It represents more than simply optical information; instead it represents a higher level of spatial organization. Transparency refers to the simultaneous awareness of many spatial locations. The position of the transparent figures conveys an ambiguous message.[64]

Geometrical distortion in the enhancement of visual acuity in 3D architectural diagrams

Physical models allow architects to create tangible, tactile representations of their designs that can be touched and manipulated, providing a more direct and immediate sensory experience. Virtual reality simulations make use of computer graphics and advanced technology to create immersive, interactive environments that simulate the physical sensation of inhabiting space. Interactive digital interfaces allow users to manipulate digital representations of a design, providing a more flexible and dynamic way to explore and understand the design. Many three-dimensional visualizations realized with two-dimensional architectural media contain information about the distorted and oblique view and depth. This information is conveyed with exploded perspectives or axonometric perspectives. These architectural diagrams can facilitate a fused sense of involvement in both the optical and tactile senses of the viewer.

Digital diagrams can be created when manual drawings are digitized or through electronic 3D modeling. Such diagrams give the impression of morphing and movement. Examples of such representations include UNStudio's flowcharts, musical notes, electrical circuit diagrams in technical books, reproduction pictures, datascapes, and randomly selected images which replace deconstruction devices. These diagrams may not only evoke the viewer's visual bodily involvement, but also the body's tactile and physical involvement.

While the precise spatial and temporal information provided by vision and auditory senses are well understood, the haptic system is particularly effective at processing the material properties of surfaces and objects. While contact through active investigation tends to direct the observer's attention to aspects of the external environment, passive touch tends to focus the observer's attention on their subjective physical experiences. With the popularization of VR, 3D pens, 3D printing, and data visualization, diagrammatic representations of digital data are becoming increasingly haptic and tangible in day-to-day human experience.[65]

As Blackwell argues, diagrams are increasingly being used in human-computer interaction. Furthermore, improved publication technologies (particularly the PostScript language) have enabled consistent reproduction of diagrams.[66] Furthermore, VR technologies with 3D audio or tactile haptic feedback mechanisms improve the sophistication of diagrammatic communication.[67] Diagrams created with VR headsets in digitally generated or immersive worlds can also be accompanied by sound, sight, scent, or can be drawn by hand in the air using technologies such as 3D pens. 3D-printed data visualizations and code-based graphics (such as Mapzilla) are examples of these new techniques and tools [Fig. 07].

Due to the physicality of material, the materiality of a 3D diagram or model that is hand-crafted or manufactured with a 3D printer necessitates different perception than analog diagrams. Touch is important in "communicative and emotional" senses.[69] Through an encounter with a design diagram, we perceive a quality of being-in-its-presence and because we engage with it to such an extent, we experience a depth of sensory engagement. The "embodiment and embodied knowledge approach to drawing" might be the reason for this.[70] Given the increasing usage of three-dimensional haptic diagrams in new and immersive technologies, the design process will likely be increasingly replaced by more haptic and inclusive environments and approaches.

Final words

While diagrams have been a means of conveying measurable data and universal knowledge (particularly in the ancient and medieval eras), they have evolved into more expressive, generative images in the postmodern era. In some cases, this has been achieved through the replication of multiple images extracted from the original context and given new value. As a result, these diagrams become difficult-to-decipher representation of tacit information. The objecthood of haptic diagrams can be tactile and informative, stimulating ways of thinking to bridge the gap between representation and reality and better engage with the designer's embeddedness in the act of thinking and designing. They act as intermediaries between the designer, the architectural product, its representation, and the perceiver. Touch as a design thinking interface in architectural diagrams can help the designer to be more physically immersed in the process, both methodologically and in terms of the result.

Diagrams are ocular because they first establish their own universe of knowledge and experience, whether through a representational, a design or inquiry tool, or the result of a clearer and explicit mapping (such as dreamscapes). The combined effects of linearity, contrast, perspective, and distortion or fragmented linkages is perceived visually. On the other hand, Haptic diagrams correspond with a combination of sight and touch. They are physical at the same time, not only because they are created by hand using diverse interfaces in traditional or digital media, but also because they manipulate the physiological reality of touch. As with volvelles, knowledge is only extended through the body, and its embodiment comes through face-to-face encounters. In digital or immersive environments, this takes the form of information articulation via a pseudo-haptic interface or interaction. The haptic refers to tactility only for those who can physically touch the diagram. If contact is not possible, a perceiver experiences it as a pseudo-haptic experience.

Diagrams produce meaning allegorically through abstract and incomplete relations of meaning. The necessity for touch in haptic diagrams encourages the perceiver to gather information via experience and to follow impulse rather than picturing spatial information and numerically deciphering the forms conveyed in diagrams. This experience is transformed into a puzzle when transparent, tactile, or fragmented elements are included in diagrams. Meaning emerges both in the middle and at the end of a path through a diagram. The viewer must uncover and synthesize diagrammatic information between representations and multiple sources.[71]

Instead of increasing the vividness of visual communication in the design process, 3D haptic architectural diagrams might increase the spatiality of the design methodology. The digitization of transparent or superimposing layers or diverse materials can also boost the efficacy of diagrams. What advantages does the tactility of diagrams offer designers? Architects can investigate and comprehend the spatial and sensory qualities of their designs by developing haptic architectural diagrams. This can help them better embody their designs and comprehend how others will interact with them physically. Haptic diagrams can also help architects communicate with those perceiving their diagrams by offering a tangible, tactile representation of the design. Cognitive and other somatosensory testing is required to understand the extent of this communication.

1. Ana Vasconcelos, "Digital Diagrams in Contemporary Architectural Design: A Creative Interface Between Human Imagination and Form," in *Advances in Human Factors in Architecture, Sustainable Urban Planning and Infrastructure, Proceedings of the AHFE 2021 Virtual Conference on Human Factors in Architecture, Sustainable Urban Planning and Infrastructure*, July 25-29, 2021, USA, ed. Jerzy Charytonowicz, Alicja Maciejko, and Christianne S. Falcão (Switzerland: Springer Nature, 2021), 109, https://doi.org/10.1007/978-3-030-80710-8_14.
2. Robin Evans, "Translations from Drawing to Building," in *AA Files* 12 (Summer 1986), accessed July 11, 2023, https://www.jstor.org/stable/29543512.
3. Jennifer A. E. Shields, "Displacement: Architectural Collage, Investigating Atmospheres in a Design Studio," in *Proceedings of the 4th International Congress on Ambiances, Alloaesthesia: Senses, Inventions, Worlds, Réseau International Ambiances* (December 2020): 339, https://doi.org/10.48537/hal-03220336.
4. In philosophical contexts, Deleuze and Guattari mentioned a diagram as something that "does not function to represent even something real, but rather constructed a real that is yet to come, a new type of reality" (Gilles Deleuze and Felix Guattari, *A Thousand Plateaus,* trans. Brian Massum (Minneapolis: University of Minnesota Press, 1987), 141).
5. Pari Riahi, "Expanding the Boundaries of Architectural Representation," *The Journal of Architecture* 22, no. 5 (2017): 816, 821, https://doi.org 10.1080/13602365.2017.1351671.
6. Michael Friendly, "Milestones in the History of Thematic Cartography, Statistical Graphics, and Data Visualization," 2008, 1, accessed January 07, 2022, https://www.usu.edu/math/symanzik/teaching/2009_stat6560/downloads/friendly_milestone.pdf.
7. Shields, "Displacement," 339-340.
8. Andrew Chaplin, "The Architecture of Diagrams: A Taxonomy of Architectural Diagrams," 1-51, accessed October 03, 2022, https://issuu.com/andrew-chaplin/docs/architecture_of_diagrams.
9. Chaplin, "The Architecture of Diagrams," 1-51.
10. Ellen Yi-Luen Do and Mark D. Gross, "Thinking with Diagrams in Architectural Design," Artificial Intelligence Review 15 (2001): 136, https://doi.org/10.1023/A:1006661524497.
11. Thora Tenbrink, Ruth Conroy Dalton, and Anwen Jago Williams, "The Language of Architectural Diagrams," in COSIT 2019: 14th Conference on Spatial Information Theory, ed. Sabine Timpf, Christoph Schlieder, Markus Kattenbeck, Bernd Ludwig, and Kathleen Stewart (Dagstuhl Publishing, 2019), 23:3, https://doi.org/10.4230/LIPIcs.COSIT.2019.17).
12. Bill Hillier, Space is the Machine: A Configurational Theory of Architecture (London: Space Syntax, 2007), 12.
13. Hillier, *Space is the Machine*, 32.
14. As cited by Tenbrink, Dalton, and Williams, "The Language of Architectural Diagrams," 23:3.
15. Op. cit. 23:4.
16. Hillier, Space is the Machine, 17.
17. Georg Vrachliotis, "Articulating Space Through Architectural Diagrams." in *AAAI Spring Symposium: Reasoning with Mental and External Diagrams: Computational Modeling and Spatial Assistance,* Technical Report SS-05-06 (2005), 127-133, Stanford, California, March 21-23.
18. Vrachliotis, "Articulating Space Through Architectural Diagrams," 127-133.
19. Riahi, "Expanding the Boundaries," 816.
20. Gerrit Confurius, "Editorial," *Daidalos* 74 (2000): 4-5.
21. Fraser Shields, "*Diagrams in Architecture an Examination of Diagram Based Design Methods in Contemporary Urban Architecture Projects*" (Master's thesis, School of Architecture of Victoria University of Wellington, 2012), 20, http://hdl.handle.net/10063/2179.
22. Shields, "*Diagrams in Architecture,*" 56-58.
23. Taxonomically different from Shields's classification, Chaplin mentions that there are planimetric, sectional, axonometric, programmatic, contextual, circulation, structural, scaled, sequential, generative, topological, euclidian, pertaining to a visual field, pertaining to senses, parti diagrams and post facto explications (Archisoup. "Understanding Architectural Diagrams," accessed February 01, 2023, https://www.archisoup.com/studio-guide/architectural-diagrams).
24. Steve Pile, "'The Problem of London', or, How to Explore the Moods of the City," in The Hieroglyphics of Space: Reading and Experiencing the Modern Metropolis, ed. Neil Leach (London and New York: Routledge, 2002), 212.
25. Bernard Tschumi's deconstruction work in the 1970s represented the movement in space as a juxtaposition of event cities combined with dance notation systems in the design of La Villette park. Similarly, Eisenman derived from a juxtaposition of the "historical analysis of modernism" and of structural linguistics (Anthony Vidler, "Diagrams of Diagrams: Architectural Abstraction and Modern Representation," Representations 72 (2000): 3).
26. Rem Koolhaas's collages of the 1970s inspired by the Italian utopian projects of the 1960s, and Mies van der Rohe's collages borrowed from the Berlin Dadaists of the 1920s, Lebbeus Woods and Archigram's works are some examples (Jesús Vassallo, "Seamless: Digital Collage and Dirty Realism in Architecture," *Log* 39 (Winter 2017): 58).
27. Henri Focillon and Victoria Charles, *In Praise of Hands* (New York: Parkstone Press International, 2018).
28. Josephina Concannon, "A Review of Research on Haptic Perception," The Journal of Educational Research 63, no. 6 (1970): 250-252, http://www.jstor.org/stable/27535980.
29. Charles Edoudard Jeanneret (Le Corbusier), Modulor I and II, Modulor 2: Let The User Speak Next, trans. Peter de Francia, and Anna Bostock (Cambridge, Massachusetts: Harvard University Press, 1980), 153 (originally in 1958).
30. Frederik Stjernfelt, Diagrammatology: An Investigation on the Borderlines of Phenomenology, Ontology and Semiotics (Dordrecht: Springer, 2007).
31. Owens, "The Allegorical Impulse: Toward a Theory of Postmodernism," *October* 12 (1980): 75, https://doi.org/10.2307/778575.
32. Owens, "The Allegorical Impulse," 69-71.
33. Paolo Papale, Leonardo Chiesi, Alessandra C. Rampinini, Pietro Pietrini, and Emiliano Ricciardi, "When Neuroscience 'Touches' Architecture: From Hapticity to a Supramodal Functioning of the Human Brain," Front. Psychol. 7, no.866 (2016): 5, https://doi.org/10.3389/fpsyg.2016.00866.
34. Papale, Chiesi, Rampinini, Pietrini, and Ricciardi, "When Neuroscience 'Touches' Architecture," 2, 5.
35. Juhani Pallasmaa, The Thinking Hand: Existential and Embodied Wisdom in Architecture (UK: Wiley, 2009), 91.
36. Pallasmaa, The Thinking Hand, 91-92.
37. Op. cit. 91-92.
38. Evans, "Translations from Drawing to Building," 5.
39. Richa Gupta, M. Balakrishnan, and P.V.M. Rao, "Tactile Diagrams for the Visually Impaired," IEEE Potentials, *Assistive Technology,* (January/February 2017): 14, https://doi.org/10.1109/MPOT.2016.2614754.
40. Rudolf Arnheim, Art and Visual Perception: A Psychology of the Creative Eye (Berkeley and London: University of California Press, 1997), 258 (originally 1954).
41. Rudolf Arnheim, The Dynamics of Architectural Form (Berkeley and Los Angeles: University of California Press, 1977), 110-111.
42. Marcus Pollio Vitruvius and Daniele Barbaro, *I dieci libri dell'architettura di M. Vitruvio tradutti et commentati da Monsignor Barbaro eletto patriarca d'Aquileggia* (In Vinegia: 1556), ETH-Bibliothek Zürich, Rar 9902, per Francesco Marcolini, Public Domain Mark, 265, https://doi.org/10.3931/e-rara-7582.
43. Amaranth Borsuk, The Book (Cambridge, Massachusetts: MIT Press, 2018).
44. Vitruvius and Barbaro, *I dieci libri dell'architettura.*
45. James J. Gibson, "The Perception of Visual Surfaces," The American Journal of Psychology, 63, no. 3 (1950): 367, accessed March 19, 2023, https://www.jstor.org/stable/141800.
46. Gibson, "The Perception of Visual Surfaces," 368-370.
47. MOMA, Lebbeus Woods, accessed August 20, 2023, https://www.moma.org/collection/works/88853.
48. Chris Kenny, *Maidenhead Thicket,* Map Works, accessed August 25, 2023, https://www.chriskenny.co.uk/map-works/l49nbyov7tmz6pow10i4b3fdf9cbyb.
49. Ben Spong, Designing a dialogue, accessed July 17, 2023, https://benspongarch.tumblr.com/post/130199472109/ben-spong-designing-a-dialogue-a-small-selection/amp.
50. Sarah Size, Works, accessed February 17, 2023, https://gagosian.com/artists/sarah-sze/.
51. Katsumi Hayakawa, *Multilayer Structure,* accessed August 23, 2023, http://katsumihayakawa.com/mlstructure.html.
52. Fernando Cecilia Márquez and Richard Levene, ed., "Glass Pavilion at the Toledo Museum of Art," in *El Croquis 139: SANAA. Kazuyo Sejima Ryue Nishizawa. 2004-2008, Architectural Topology* (Madrid: El Croquis Editorial, 2008), 86.
53. Arnheim, Art and Visual Perception, 253, 257.
54. Raymond Lucas, "The Discipline of Tracing in Architectural Drawing," in The Materiality of Writing: A Trace-Making Perspective, ed. Christian Mosbæk Johannessen and Theo van Leeuwen (Routledge: London and New York, 2018), 124.
55. Louis Olcott Price, *Line, Shade and Shadow: The Fabrication and Preservation of Architectural Drawings* (Houten: Hes & De Graaf Publishers, 2010).
56. Lucas, "The Discipline of Tracing in Architectural Drawing," 130, 134, 135.
57. Op. cit. 135.
58. James J. Gibson, The Ecological Approach to Visual Perception (New York, East Sussex: Psychology Press, 1986).
59. Shaun Murray, "Abducted Ground: The Ineffaceable Beaduric's Island," AIS - Architecture Image Studies Scientific Journal: Narrative Architecture 1, no. 2 (2020): 109, https://doi.org/10.48619/ais.v1i2.326.
60. Robin Wilson, "World Shaping: Choreographies of Mapping and Construction," *Architectural Design (AD)* 92, no. 4 (2022): 72, https://doi.org/10.1002/ad.2837.
61. Jennifer A. E. Shields, Collage and Architecture (New York and Abingdon: Routledge, 2014), 59.
62. Esen Gökçe Özdamar, "*A Re-reading of Narrative of Contemporary Housing in Context of Urban Dynamics: Istanbul, Vienna, Amsterdam*" (PhD dissertation, Istanbul Technical University, 2011), https://polen.itu.edu.tr/items/ade167fa-0aea-47a5-a0e0-c51cc2a37348.
63. Basarab Nicolescu, *Manifesto of Transdisciplinarity* (USA: Suny Press, 2002).
64. Colin Rowe and Robert Slutzky, "Transparency: Literal and Phenomenal," *Perspecta* 8 (1963): 45, https://doi.org/10.2307/1566901.
65. Susan J. Lederman and Roberta L. Klatzky, "Haptic Perception: A Tutorial," Attention, Perception, & Psychophysics 71, no. 7 (2009): 1439, https://doi.org/10.3758/APP.71.7.1439.
66. Alan F. Blackwell, ed., "Introduction: Thinking with Diagrams," *Artificial Intelligence Review* 15, no. 1-2 (2001): 1, https://doi.org/10.1023/A:1006673610113.
67. Paul Brna, Richard Cox, and Judith Good, "Learning to Think and Communicate with Diagrams: 14 Questions to Consider," *Artificial Intelligence Review* 15, no. 1-2 (2001): 131, https://doi.org/10.1023/A:1006584801959.
68. Mapzilla, "NACIS," accessed February 01, 2023, https://mapzilla.co.uk/work/nacis.
69. Alberto Gallace and Charles Spence, "The Cognitive and Neural Correlates of Tactile Memory," Psychological Bulletin 135, no. 3 (2009): 380-406, https://doi.org/10.1037/a0015325.
70. Lucas, "The Discipline of Tracing in Architectural Drawing," 133.

Diagram
Haptic
Perception
Embodiment