

# The Active Voice of Architecture: An Introduction to the Idea of Chance

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In this text I hope to present a preliminary inquiry into the idea of chance in architecture and to begin a discussion on the theorisation of chance in the process of design. To a certain extent the institution of architecture is interested in making predictions — this is how chance enters in the process of design, as a creative play of probabilities. This play can be impulsive, systematic, active, or a combination of these — a number of examples from the arts give us critical ground to explore preferred ways of ‘using’ chance in design. But when designs are realised as built environments chance takes a forceful and unpredictable role: it becomes a synthesising function of space, time, and the on-lookers, constantly influencing the equilibrium of forces that constitutes experience. Buildings attempt to frame but sustain this equilibrium and within it negotiate architecture’s defence against the real. This architecture, call it *architecture of chance*, is *all* architecture: it is the architecture of the moment, indeterminate, vulnerable to accidents, but constructively so; it gains from failures and imperfections, and accepts chance as an essential element of existence.

## Unnoticed Beauty

Chance, in the form of coincidence and simultaneity, is inseparable from our experience of space and time. The activity around the dining table at a specific moment, the sound of the passing train, a bright reflection on the window, the sudden opening of the door, the coming of the evening storm and the rear garden’s smell, all these orchestrate a spatiality that is based more on chance factors and relationships than on design. It is this modest simplicity of chance, fleeting and hardly noticeable or spoken about, that builds up architectural experience’s magical complexity and everyday beauty. This beauty, I suggest, is what André Breton meant by ‘the marvellous’, beautiful reality made by chance. The architecture of the moment, its calm or terror, requires subject-object relationships that architects can influence to only a limited degree. While inhabiting an architectural environment, chance and its greater realm of indeterminacy play crucial roles in influencing these relationships and in possibly reshaping the architects’ initial work.

Chance may mean an event proceeding from an unknown cause and thus ‘the equivalent of ignorance in which we find ourselves in relation to the true causes of events’.[1] But it may also mean the unforeseen effect of a known cause. Although we go about our everyday lives and to a certain extent produce space, with a view to fending off the unknown aspect of existence, we often note a furtive enjoyment related to the unpredictability of chance. Even modern societies, which believe in causality and the impossibility to fully predict the future, secretly enjoy oracles related to chance. Throughout history many cultures have seen chance as having a sacred and magical power. Greek mythology, for example, tells us how *Tuché*, the goddess of chance, is superior in her say about people’s fates to that of all the other gods (even *Zeus*, the leader of the gods). But the civilisation most exclusively preoccupied with chance as central to the world’s order is the Chinese. While the West accepts the role of chance primarily in opposition to causality, chance in China and most of the Far East is understood as an independent concept deeply embedded in life:

What we call coincidence seems to be the chief concern of this peculiar [Chinese] mind, and what we worship as causality passes almost unnoticed. We must admit that there is something to be said for the immense importance of chance. An incalculable amount of human effort is directed at restricting the nuisance or danger represented by chance. Theoretical considerations of cause and effect often look pale and dusty in comparison to the practical results of chance.... The matter of interest seems to be the configuration formed by chance events in the moment of observation.... While the Western mind carefully

sifts, weighs, selects, classifies, isolates, the Chinese picture of the moment encompasses everything down to the minutest nonsensical detail, because all of the ingredients make up the observed moment.[2]

The Chinese picture of the moment is a *chance image*. It encompasses all minuscule impressions of reality simultaneously present.[3] It anticipates ‘the possible’ and appreciates chance as a mediator for beauty and change.

### **Habit and Accident**

For Marcel Duchamp the possible is an ‘infra-thin’: a passage between two states, a ‘paper-thin separation’ between two very similar conditions that happens in the interval of a second. He writes:

The possible / is an infra-thin —...

The possible implying / the becoming — the passage from / one to the other takes / place / in the infra thin. / allegory on ‘forgetting’...

Sameness / similarity ... / In time the same object is not the / same after a 1 second interval...

The warmth of a seat (which has just / been left) is infra-thin...

Subway gates — The people / who go through at the very moment / infra-thin...[4]

The infra-thin is an ethereal quality that characterises the thinnest possible slice of space — reaching sameness — and the shortest possible duration in time — reaching synchronicity. It exists between visibility and invisibility and emerges in tiny details that quickly escape our attention.

According to Henri Bergson we, involved in many similar daily actions, become ‘conscious automata’ and respond to our environment with ‘reflex acts’. This kind of perception depends on memory, resemblance and familiarity. It is not conscious or specifically motivated; it is just automatic. We go down a staircase without thinking and guided by habit, for instance, because we have memories of doing this many times before. But habit protects us from the plethora of information that surrounds us and the confusing and indeterminable changes of our environment by making us inattentive.[5] Through protecting ourselves in this way, we are menaced by a sense of repetition and boredom. An accident can then act as an antidote to this vicious circle to disrupt our routines with novelty.

The human ability to design and produce ideas within different registers of thought is evidence of the operations of the infra-thin. However, the spatial register of the passing of the infra-thin cannot be easily grasped. Chance can rupture its passing to reveal a possibility for change. This is why it is important to architecture, as it is to any creative process.

### **Design *In* and *As* Play**

Nearly all our ordinary actions require an understanding of chance, the notion of probability and the ability to automatically estimate the likelihood of expected events. We know, for instance, there is a better chance to see a leaf falling if we stare at a tree for hours rather than for a second. But is such a strong and frequent intuition based on a gradual understanding of probability, acquired empirically, or is the concept of chance inborn? Jean Piaget and Bärbel Inhelder investigated whether the intuition of chance is as fundamental as, say, that of whole numbers. Through a number of experiments with chance (meaning here the interaction of independent causal series), they demonstrated that young children have no concept of chance.[6] This is because they have neither a concept of law nor a concept of design as an ordered

operation. Design and chance are fundamentally interdependent ideas, which start emerging and evolving in one's consciousness after the age of seven.[7] The two ideas when woven together in play are especially attractive for adults. Neither intuition nor conscious logic can affect the result of the cast of a die but, though aware of this, we are often tempted to guess the result and bet on it. This pleasure perhaps reflects a desire to overthrow our gradually acquired logic and attachment to causality, at least temporarily, and return to that naïve age of ignorance when we understood neither design nor chance. This principle of pleasure in coupling design and chance is necessary in all creativity.

Duchamp, who was deeply interested in the interaction of skill and chance, makes the following remarks about the pleasure of playing chess:

The aesthetic pattern that develops on the chessboard seemingly has no visual aesthetic value and is similar to a sheet of music, which can be played over and over. Beauty in chess is much closer to the beauty of poetry; the chess pieces are the alphabet that shape the thoughts; and although these thoughts form a visual pattern on the chessboard, they express beauty in the abstract, like a poem. I really believe that every chess player experiences a mixture of two aesthetic pleasures; first the abstract image, which is closely related to the poetic idea in writing, and then the sensual pleasure involved in the ideographic representation of that image on the chessboards. Based on my own close contact with artists and chess players, I have come to the personal conclusion that although not all artists are chess players, all chess players are indeed artists.[8]

Playing chess means formulating a strategy, a number of moves, which although dependent upon the rules of the game and the opponent's performance are also independent actions with particular objectives. While the game unfolds as a complex field of relationships and movements, numerous possible patterns are shaped mentally and abstractly projected onto the chessboard. The sophisticated 'alphabet' of chess provokes inspiration but always within a framework of causality in which the game unravels. Naturally, each game is unique. The process can be paralleled with the creative freedoms and limitations involved in the course of architectural design. The aesthetic pleasure of coupling chance and skill in play can be similar to the aesthetic pleasure involved in architectural drawing and making, at least when the design process is both imaginative and reflective.

### **Impulsive Chance**

The interplay of necessity and chance has been a principal concern in the creative consciousness of the world throughout history. But, contrary to philosophy, science, and the arts, architecture has not sufficiently interrogated the idea of chance in its own production. Architecture's dominant theories and practices have hardly pursued, at least not openly, the thought that chance may be a positive agent in the different stages of architecture, from design conception to construction and use. Is this partly because the actions of chance question the architect's authorial control? Is it also because they challenge one of architecture's elementary purposes to defend itself against the contingencies of physical reality? After all most buildings try to offer protection against the environment and construct an order within its chaotic and unpredictable facets. Architecture's resistance to chance is however contested by a number of radical approaches in the arts. The pressures on architects are different from those on artists but it is worth examining how others have engaged with chance and what they can possibly offer to architects and vice versa. As I will show it is also important to realise that although artists, more often than architects, have been consciously drawn to chance, architecture's troubled relationship with chance is not unknown in the arts.

Dada's employment of chance, for example, was linked to an intense opposition to art as a practice based on formal and rational values. Its reliance on chance was part of a greater anti-artistic perspective, a general attack on rationality, which frequently became an overpowering concern. Gradually chance-related operations became prescribed and unsatisfactory to many Dada artists. Richter notes:

We were all fated to live with the paradoxical necessity of entrusting ourselves to chance while at the same time remembering that we were conscious beings working towards conscious goals. This contradiction between rational and irrational opened a bottomless pit over which we had to walk. There was no turning back; gradually this became clear to each of us in his own secret way.[9]

Finally, Dada realised the relationship between design and chance was more complex: ‘... the realisation that reason and anti-reason, sense and nonsense, design and chance, consciousness and unconsciousness, belong together as necessary parts of a whole — this was the central message of Dada.’[10]

The surrealists cultivated the use of chance differently from Dada. They saw the outcome of their well-celebrated ‘automatism’ as a point of departure for further elaboration, something that subsequently required skilful work. Joan Miró, for instance, would be stimulated to paint through a mistake or an accidental, which for others was an insignificant detail. He called this a ‘shock’: ‘I begin my pictures under the effect of a shock I feel that makes me escape reality. The cause of this shock can be a little thread out of the canvas, a drop of water falling, that fingerprint I’ve left on the brilliant surface of the table.’[11]

It is clear that Freud’s investigations of the unconscious workings of the mind and the meanings he assigned to symptoms and such everyday phenomena as mistakes, jokes, dreams or slips of the tongue, greatly influenced the artistic modes of the first part of the twentieth century. Freud’s thought encouraged chance to be seen as *impulsive*: an intuitive mechanism of creativity that could ‘unlock’ unconscious desire to escape the Cartesian thought. This kind of impulsive chance, artists thought, could assist plunges into indeterminacy, offering momentary glimpses of an a-causal world that transcends existing knowledge. On the other hand scientific theories of the period related to new conceptions of time, probability, and the principle of uncertainty pointed to *systematic* notions of chance.

### **Active Chance**

A fascinating range of theories and practices of chance can be traced in the humanities as well as the social and natural sciences of the twentieth century, from literature and music to economics and biology. The history of this development and its full implication in our area under discussion is too big to review within the limits of this paper. But it is useful to isolate another example: the contrasting position to Surrealism and Dada as expressed by the Situationist International.

The Situationist International were suspicious of the unconscious as a creative source and disputed the surrealists’ absolute fidelity to it. ‘We know that the unconscious imagination is poor, that automatic writing is monotonous, and that the whole genre of ostentatious surrealist “weirdness” has ceased to be very surprising’, Guy Debord writes.[12] By distrusting the surrealists’ search for the unconscious, the Situationist International also distrusted the spontaneous use of chance.[13]

However, chance was a significant factor in their practice of *dérive*. The constantly changing psychogeographical relief of the city and its diverse microclimates and centres of attraction made the *dérive* a practice of unpredictable wandering. But Debord hurries to indicate a danger:

[...] the action of chance is naturally conservative and in a new setting tends to reduce everything to an alternation between a limited number of variants, and to habit. Progress is nothing other than breaking through a field where chance holds sway by creating new conditions more favourable to our purposes [...] The first psychogeographical attractions discovered run the risk of fixating the *dériving* individual or group around new habitual axes, to which they will constantly be drawn back.[14]

Hermetic processes which become strictly methodical are likely to exclude pure chance. Pure chance has to embrace indeterminacy and the possibility of change. It has to be *active*, in other words to operate dynamically in time.

Through the experience of the *dérive* the Situationist International aimed to arrive at objective and determinate conclusions about the city that could be utilised to inspire a new consciousness about urbanism and about architecture. Yet the *dérive* was not a determinate act in itself and did not exclude chance. Accidental rendezvous and conversations with unknown passers-by, weather contingencies, 'vague terrains' of leftover spaces, hidden back streets layered overtime, and 'emotional disorientings', all led to discoveries of unforeseen 'unities of ambiance'. These discoveries were achieved by enabling two types of chance: the impulsive chance of the group or individual (based on hidden unconscious forces) and a kind of *active* chance operating through time within the complex forces of the city. Whether or not the Situationist International admitted it, the *dérive* was a positive practice of employing chance, arising collectively and in time as an expansive indeterminate drawing of action on the surface of the city.

If chance is always present in our experience of the city and of architectural artefacts, it then comes as a surprise that architects have not sufficiently considered it during the design process. The above examples are only a selection from the many artistic, political and scientific movements of the twentieth century that engaged with chance.[15] The diversity of the approaches and, at times, their contradictory philosophical positions can offer architects valuable ground for critical reflection.

### **Pseudo-indeterminacy**

Bernard Tschumi has based many of his ideas in cinematic montage and has defined architecture as 'making room for the event'. His proposals are relevant to our discussion of chance and indeterminacy as he argues for an 'architecture of event' and an 'architecture of disjunction' where space, movement, action and event can permeate each other. However, in his *Manhattan Transcripts* (1981) the trio of movement, action and event is manifested as a translation of bodily movement into fixed curved walls and corridors. When fluid action is translated to solidified concrete form, Tschumi achieves not an open space, an architecture of event and action, but a restricted space, an architecture of control.

In his built project of Le Fresnoy, the National Studio for Contemporary Arts in Tourcoing (1997), Tschumi attempts to offer an ambiguous space between the new large roof and the lower building it shadows. The large roof acts as a hangar offering a void between itself and the rest of the building, which is left undetermined and in a sense useless. Tschumi explains: 'what interested us most was the space generated between the logic of the new roof (which made it all possible) and the logic of what was underneath: an in-between, a place of the unexpected where unprogrammed events might occur, events that are not part of the curriculum.' [16] In Le Fresnoy the significance, according to Tschumi, lies in the in-between, the unexpected. But Tschumi's emphasis on the indeterminate possibilities of Le Fresnoy is false. The project is characterised by *pseudo-indeterminacy*: it leaves some space for unprogrammed events but, I would argue, not necessarily more than other buildings.

In modernist architectural discourse indeterminacy in buildings is usually discussed in terms of flexibility, a term associated with function and efficiency. A flexible building should allow change. This may be done by redundancy, the absence of determined content or use. But useless and empty spaces are no more vulnerable to chance than ones with a predetermined use. A building may also provide flexibility by technical means, a system for rearranging components, say.[17] But by designing a building as flexible in mechanical terms, the architect defines how the building can change, trying rather to control its appearance and use.

Indeterminacy in architecture does not just mean flexibility. Flexible and inflexible buildings can equally, although differently, provoke doubt and possibilities for the unexpected.

Unpredictable chance can affect all types of building, whether flexible or not, functional or not. There is no definite boundary where design ends and chance takes over.

### **Interrogating the Real**

Our perceptual experience cannot claim objectivity and certainty; it involves instead a great range of indeterminacy. Jacques Lacan's dialectic of the eye and gaze shows that psychologically subject and object are not absolutely distinct. A sense of contact between subject and object on the screen of representations affects perceptual experience in ways that cannot be determined.[18] Whether the unconscious is seen as a subjective mechanism in Lacan's terms or a collective one in C.G. Jung's terms, a mistake, dream or accident, ruptures one's habits; it causes disturbance, a 'noise' in the field of experience. Simultaneously, it brings into light a glimpse of something initially invisible.

Accidents operate beyond the realm of representations: they cannot be forecasted or drawn. Their presence in the architectural process should be particularly welcomed because it brings to the front an element of the real. In his book on photography, *Camera Lucida*, Roland Barthes defines a relevant term, the 'punctum'. Closer than the Lacanian gaze to the accident, it is 'this element which rises from the scene, shoots out of it like an arrow, and pierces me'. [19] The 'punctum' is a 'sting, speck, cut, little hole — and also a cast of the dice. A photograph's 'punctum' is that accident which pricks me (but also bruises me, is poignant to me)'. [20] The 'punctum' is the effect of what the Greeks call *tuché*, which Lacan translates as 'the encounter with the real'. [21] *Tuché* is an aspect of reality that the spectators are not aware of until they encounter a rupture in their representational field. The rupture comes unexpectedly and interrupts the norm of one's perception. Its location is confusing but it has the potential to expand and affect the meaning of the whole. Although causality can explain its presence, from the spectator's viewpoint the 'punctum' is an addition to the picture that is offered as if by chance. As a result of chance, not design, the 'punctum' is not determined by morality or aesthetics.

Architecture is being shaped by planned and unplanned actions, logic and chance. But what kind of architectural ideas does the acceptance of chance untangle? What kind of practices does it invite? The design tools we choose are not innocent as they imply different kinds and degrees of control. Which working tactics can help us achieve a positive distance from the expected for revelation to emerge? An engagement with chance in the design process might mean the use of impulsive or systematic processes, which remind us of experimental techniques used by avant-garde writers or musicians such as Stéphané Mallarmé, Iannis Xenakis or John Cage.[22] But an engagement with chance might also mean the opposite: acknowledging the role of chance in the experience of the users of architecture but rejecting its function as a design tool. In the second case the design process would aim to generate a simple architectural framework where chance can be lived, felt and celebrated. In any event a truly creative engagement with chance would be able to challenge deterministic approaches to design, functionalism, taste and authorship.

The history of architectural design is dependent on the parallel history and evolution of our attitude to indeterminacy and chance. It is time to write an account of the evolution of the idea of chance from the early avant-garde scenes of fine art, design, and performance of the twentieth century, to the current condition of virtual and mixed realities.[23] Such an account would be fascinating for architecture, design culture, and the broader histories and theories of creativity. It would highlight how architecture has ignored chance or has engaged with it in hesitant and unspoken manners, sometimes even with guilt. We can uncover different conceptions of chance in the work of Cedric Price, Bernard Tschumi, Rem Koolhaas, and Coop Himmelblau, and less successfully in the work of Peter Eisenman, Daniel Libeskind and Frank Gehry, for example. These works offer a limited and not always a positive account on the subject, yet a good foundation.

There is almost no published literature on the subject of chance in architecture. This is why I have deliberately given many heterogeneous references, mainly outside architecture. I consider them crucial if we are to take a holistic approach to the subject. These sources of course require further analysis and interpretation. So the purpose of this paper is foundational: to begin a conversation about the principles, operations and formations of chance and ask if and how architectural practice might theorise chance. Beauty, play, impulse, and the encounter with the real are key issues I have pointed to. But, if this introduction aims at something, it is a definition of architecture as an embracing agent of the indeterminate. To a certain extent the institution of architecture is interested in making predictions — this is how chance enters in the process of architectural design, as a play of probabilities. But when designs are realised as built environments chance takes an even stronger role: it becomes a synthesising function of space, time, and the on-looker, constantly influencing the complex equilibrium of forces that constitute experience. Architecture is the practice of sustaining this equilibrium: confronting indeterminacy, appreciating and at times purposefully enabling the performance of chance rather than trying to rule it out. This architecture, call it *architecture of chance*, is all architecture: it is the architecture of the moment, vulnerable, but constructively so, to accidents; it gains from failures and imperfections, and accepts chance as an essential part of existence. Chance is the only real and radical voice architecture has. We should nurture it.

*My warmest thanks to Dr Victoria Watson who made critical suggestions during the writing of this piece.*

- [1] David Hume quoted in Harriett Ann Watts, *Chance: A Perspective on Dada* (Ann Arbor: UMI Research Press, 1980), p. 155.
- [2] Carl Gustav Jung in Richard Wilhelm and Cary F. Baynes, *The I Ching or Book of Changes* (New Jersey: Bollingen Foundation & Princeton University Press, 1977), pp. xxii–xxiii.
- [3] For Jung the interdependence of events and observers is based on an a priori principle he calls ‘synchronicity’: the occurrence of *meaningful* coincidences in space and time, which he regards as an ‘acausal connecting principle’. He writes: ‘it seems [...] necessary to introduce, alongside space, time and causality, a category which not only enables us to understand synchronistic phenomena as a special class of natural events, but also takes the contingent partly as a universal factor existing from all eternity, and partly as the sum of countless individual acts of creation occurring in time.’ See Jung, *Synchronicity: An Acausal Connecting Principle* (London: Ark, 1991), p. 143
- [4] Marcel Duchamp, *Notes* (Paris: Centre National d’Art et de Culture Georges Pompidou, 1980), unpaginated.
- [5] For, ‘to regain control of ourselves in the midst of the moving bodies, the circulation of their contours, the jumble of knots, the paths, the falls, the whirlpools, the confusion of velocities, we must have resource to our grand capacity of forgetting’. Paul Valéry quoted in Jonathan Crary, *Suspensions of Perception: Attention, Spectacle, and Modern Culture* (Cambridge: MIT Press, 1999) p. 299. See also Henri Bergson, *Matter and Memory* (1896) (New York: Zone Books, 1988).
- [6] The definition of chance as the interaction of independent causal series is given by the mathematician and economist Antoine-Augustin Cournot (1801–77).
- [7] Piaget and Inhelder explain that four-to-seven year olds make decisions about future occurrences in an emotional manner not based on probabilistic considerations and fail to differentiate between the possible and the necessary. Seven-to-eleven year olds discover the existence of chance but only through its antithesis to tangible operations of organisation and order they can now perform. They also understand the irreversibility of chance configurations. Finally, at eleven or twelve years children can deal both with tangible and imagined operations. In this way they can construct a synthesis between the mechanisms of chance and of operations, and gradually organise better their judgement of probability. See Jean Piaget and Bärbel Inhelder, *The Origin of the Idea of Chance in Children* (London: Routledge & Kegan Paul, 1975)

- [8] Duchamp quoted in Kornelia von Berswordt-Wallrabe (ed.), *Marcel Duchamp Respirateur* (Schwerin: Staatliches Museum Schwerin, 1999), p. 22.
- [9] Hans Richter, *dada: Art and Anti-Art* (London: Thames and Hudson, 1965), p. 61.
- [10] *Ibid.*, p. 64.
- [11] Joan Miró quoted in J. H. Matthews, *The Imagery of Surrealism* (New York: Syracuse University Press, 1977), p. 146.
- [12] Guy Debord in his 'Report on the Construction of Situations', in Ken Knabb (ed.), *Situationist International Anthology* (Berkeley: Bureau of Public Secrets, 1995), p. 19
- [13] Debord insists: 'the discovery of the unconscious was a surprise, an innovation, not a law of future surprises and innovations. Freud had also ended up discovering this when he wrote, "Everything conscious wears out. What is unconscious remains unaltered. But once it is set loose, does it fall into ruins in its turn?"' *Ibid.*, p. 19
- [14] Debord, 'Theory of the *Dérive*', *Situationist International Anthology*, p. 51.
- [15] For a related discussion directly linked with the process of design see Yeoryia Manolopoulou, 'Drawing on Chance: Drafting Pier 40', *Journal of Architecture*, 11(3) (2006): 303–314
- [16] Bernard Tschumi, *Event-Cities (Praxis)* (Cambridge MA: MIT Press, 1994), p. 399
- [17] See, for example, Cedric Price's idea of 'free space'. For his Generator project Price writes: 'a "menu" of items caters for individual and group demands for space, control, containment and delight.' Quoted in Stanley Mathews, *From Agit-Prop to Free Space: The Architecture of Cedric Price* (London: Black Dog Publishing, 2007), p. 245
- [18] At a sub-atomic level, events are impossible to determine except on a statistical basis. Werner Heisenberg's principle of indeterminacy, the 'uncertainty principle', shows that 'the act of observing a physical process modifies the outcome of the event, so that prediction is rendered impossible by the observer's unavoidable intervention'. Quoted in Watts, *Chance: A Perspective on Dada*, p. 155. By analogy, we can hypothesise that any act of observing can influence the observation whatever the scale of the event. The process of perceiving a building can affect the mental image and meaning of the building and, thus, the way in which it 'lives'.
- [19] Roland Barthes, *Camera Lucida: Reflections on Photography* (London: Vintage, 2000), p. 26
- [20] Barthes, *Camera Lucida*, p. 27.
- [21] Jacques Lacan, *The Four Fundamental Concepts of Psycho-Analysis* (London: Vintage, 1998) p. 53. Lacan bases his seminar 'Tuché and Automaton' on Aristotle who links the function of the cause with the notions of tuché and automaton. See Lacan, *Four Fundamental Concepts*, pp. 53–64
- [22] Contemporary aleatory practices in the performing arts can perhaps give further inspiration as they suggest time-based and interactive operations.
- [23] Significant research on the area under discussion can be found in my doctoral thesis Yeoryia Manolopoulou, *Drawing on Chance: Perception, Design, and Indeterminacy* (PhD thesis, UCL, 2003).

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