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Dissertation Title:

Order in Disorder: A Web Interaction Device Based on Visual Order and Moiré Generation

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Oral project report: https://youtu.be/NYhGOTk_rZE
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Interactive webpage of the work: https://pashacai.github.io/Order-in-Disorder/

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Contents

I. Abstract

The 'Order in Disorder' is an interactive installation art piece built upon a Javascript web platform, engaging users through intuitive keyboard and mouse manipulations to explore the emergence of visual order. This project goes beyond mere experimental overlay and rotation of random dot matrices; it represents an in-depth investigation into how moiré patterns can create order on a visual plane. In doing so, the installation uncovers underlying regularities and a sense of order hidden within seemingly random patterns, thus questioning the boundaries between order and disorder within our perceptual systems. The core inquiry stems from a profound observation of order and chaos in daily life, coupled with the ambition to offer audiences a different cognitive perspective within a digital media context. Furthermore, throughout the creation process, iterative design methodologies, user experience testing, and audience feedback have been extensively utilized for optimization. Based on collected user feedback, the study assesses the project's interactivity and engagement levels and conducts a strategic analysis of the significance of this novel mode of interaction. This paper comprehensively outlines the experimental outcomes of the project and, considering the current achievements and challenges, proposes constructive suggestions for the potential evolution of this field.

II. Introduction

The "Order in Disorder" is a practice of the above reflection, which allows users to revisit the relationship between order and disorder in digital space. By interacting with the interface elements through the mouse, people can experience and transform these seemingly random dots to discover the hidden beauty of order (Order here can be understood on a physical level as an order of things and a law, just as the seasons of the year must be spring, summer, autumn and winter. On the spiritual level, it can be understood as a feeling, why some things are disordered and why some things are orderly, and this order is a feeling, a preference that exists in the genes, and there is a universality to this preference. We'll discuss the dots issue later). This research paper details the design and development process of Order in Disorder, as well as the evaluation and refinement of its interactivity through user experience testing. It also explores how to strike a balance between interaction and content engagement in visually based digital interactions, as well as how to increase the user appeal and stickiness of such works.

III. Related Research

III.I Visual Order

In the author's view perception of visual order is limited by various factors, such as experience, habit, perception, perspective, etc. At the same time, individual differences in the perception of order can lead to different results and effects. And visual order cannot be produced without a key element, which is visual attention.

Visual attention is a multilevel selective processing process that modulates neural activity at sites such as the lateral geniculate body, due to this organisation, cortical generating neurons are in a strategic position to influence the transmission and processing of visual information from the retina to the cortex (Briggs & Usrey, 2011). Initial psychophysiological studies suggested that perceptual organisational processes were dependent on attentional processes (Kastner & Pinsk, 2004).Li & Wang (2016) in "A Review of Research on Cognitive Mechanisms of Symmetric Visual Perception" mentioned that before the perceptual organisational process was thought to be automated, the fact that it is only necessary to be in the attention is selected in the visual field to do so. In conjunction with Chan & Chua's (2003) set of visually controlled experiments, participants were asked to assess which of two lines above and below a set of dot intervals was longer. This setup was sometimes accompanied by a widening of the dots, forming arrows and potentially triggering the Müller-Lyer illusion. The results showed that participants' discrimination was unconsciously affected by the illusion even when they did not significantly notice the presence of the arrows. This phenomenon reveals that perceptual discrimination is interfered with by the illusion even when attention is not explicitly directed to the arrowheads and the direction of the arrowheads is not recognised.

This finding emphasises the intrinsic role of ordered perception in cognitive processing, suggesting a natural predisposition to order at both physiological and psychological levels. Due to limitations in neuronal processing capacity, as well as limitations in the cognitive framework itself, humans may not be fully aware of the regularities that emerge during a given time period, and sometimes this limitation leads to apparent disorder. (I am sorry to say that I cannot give a definitive answer to the question of the "disadvantages of disorder", as this topic involves more in-depth knowledge of biology, and due to the limitations of the author's field of specialisation, I can only refer to it in general terms and to the concept of "beauty". Why do we have a preference for beauty? The opposite of beauty is not ugliness, but sheer ”unbeauty”, a thing that is not beautiful, so it is not beautiful, it does not resonate with our genes, and it is not something that we pursue from the bottom of our hearts. Disorder and order here is also such a pure concept, a preference that exists in the genes.) Thus, perceived selective attention not only reflects a preference for orderliness, but may also be an unconscious manifestation of the boundaries of cognitive capacity. As Hubel & Wiesel (1959) found: most neurons are highly selective, not only for the location of visual stimuli in the visual field, but also for other properties: specific neurons respond only to visual stimuli, with orientation, direction of motion, and spatial-frequency content located in specific ranges, whose mean and width vary from neuron to neuron.

The feature of "edges" is often indispensable in visual order, and in early studies of the visual system Glass (1969) carried out a similar study of images: the Moiré Effect from Random Dots. rotated to a specific angle, a more ordered set of dots is formed due to the creation of edges.

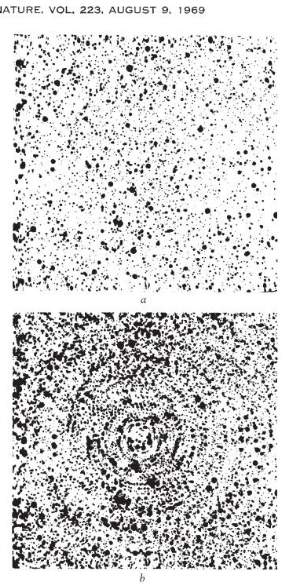

Figure 1 "Moiré Effect from Random Dots" by Leon Glass (1969)

It is easy to notice that b is much more regular than a in Figure (1). This is because the visual system effortlessly notices the large set of rotated dots, i.e., the large number of tangential edges.

Similarly Barlow & Berry (2010) have done research on perceptual modelling of visual order, and similar to the Moiré Effect from Random Dots conducted by Glass (1969), Barlow & Berry's (2010) experimental plan was to measure the ability of the human visual system to differentiate between regular, patterned features presented in an array of randomly positioned dots, pattern features. As the average density of randomly positioned dots in the array changes, the signal threshold strength of the regular features changes, but the expected relationship between the two varies depending on whether cross-correlation or autocorrelation is used to make the distinction. This approach allows inferences to be made about how human visual circuits find such visual regularities by observing the relationships followed. In their experiments Barlow & Berry (2010) used a more prescriptive way of generating these noisy images, based on the formulae Fig. (2) and Fig. (3) giving the similarity between the pixel values of one patch of the image and the pixel values of another.

$$\gamma = \frac{1}{N}\sum_{x,y}\frac{(I(x,y)-\bar{I})(T(x,y)-\bar{T})}{\sigma_I\sigma_T}, \quad \alpha = \frac{1}{N}\sum_{x,y}\frac{(I(x,y)-\bar{I})(I(x-u,y-v)-\bar{I})}{\sigma_I^2}.$$

Figure 2 & Figure 3 "Interrelationships for normalisation of 2D imagesγ" by Barlow& Berry(2010)

The difference between these two operations (sometimes referred to as first and second order for mutual correlation and autocorrelation, respectively) is important in understanding why variations in the average dot density of random dot patterns can lead to such different effects. This is because, for mutual correlation, only one of the variables added by the product has a random component, whereas for autocorrelation, both have random components. A precursor to thinking along these lines was Bela Julesz's 1962 conjecture that humans cannot distinguish between textures that have the same second-order statistic.

III.II Moiré pattern

In the discourse of visual, and arguably perceptual order, the Moiré effect plays a pivotal role as an intuitive visual phenomenon. As Bryngdahl (1974) elucidates in his seminal paper, "Moiré: Formation and interpretation", the superimposition of several periodic or quasi-periodic patterns can precipitate the Moiré effect. This arises when two transparent objects, each bearing fine stripes or grids, are overlaid, or when an object adorned with fine patterns is captured by a device with a similar pattern, such as a camera sensor, engendering an appearance marked by conspicuous contrast and interfering patterns. These patterns are not inherent to any single overlaid object but result from their relative positioning, engendering a visual effect.

The genesis of the Moiré effect is heavily contingent upon the characteristics of human visual perception. When two high-frequency patterns with differing line spacings and orientations overlap, the visual system, plagued by spatial frequency aliasing, often fails to discern individual details, merging them into a new pattern of visually lower frequency. This process involves the brain's complex post-processing of images, accentuating high-contrast edges and patterns, with certain areas undergoing contrast enhancement, rendering the patterns within these regions more prominent. Moreover, the finite resolution of human vision means that the minutest or closest details of patterns can surpass our discriminatory threshold, prompting the visual system to perceive the two patterns as one. In addition, the different facets of visual perception interact when processing these overlapping patterns, leading to the complex visual pattern of Moiré. Consequently, the Moiré effect is a unique visual phenomenon, manifesting when the eye and brain process close or overlapping high-frequency patterns. This effect is observable in the superimposition of actual physical objects, digital screen displays, captured images through camera lenses, and even within artworks.

In realms such as graphic design, photography, television broadcasting, architecture, and engineering, efforts are generally made to avert the Moiré effect, given its potential to disrupt image quality and visual appeal. Nevertheless, the Moiré effect also has its applications in both art and science, such as in the creation of distinctive visual effects in artistic design or as a means of measuring the angles, sizes, and other attributes of overlapping patterns in physics and engineering.

VI. Research Method

The study will comprehensively delineate the fundamental principles and the extensive developmental trajectory of the web-based interactive installation, "Order in Disorder". It will also test the device through experimental research, applied research, observational research, qualitative analysis, etc. and adjust the device based on the test results and feedback from the test "Order in Disorder" and optimise the device using iterative design, etc., to make the experience more fluid and the results more intuitive.

Subsequent to the refinement process, the installation will be subjected to further evaluation through data collated from participant feedback. This empirical inquiry will investigate the inherent tendencies of individuals towards the perception of visual order. Moreover, a categorization and comparative analysis of visual data, derived from the feedback, will be undertaken. This analysis is purposed to ascertain the degree to which the installation aligns with the author's investigative criteria regarding visual order. Through this scholarly pursuit, the research will evaluate the efficacy of the installation in meeting the exploratory needs posited by the author.

V. Design Process

V.I Design Concept

The concept of "order in Disorder" stems from the author's experience studying visual communication design during his undergraduate studies. At that time, the author was deeply perplexed and intrigued by the formation of visual order, especially in layout design.Some seemingly haphazard elements can be combined with each other to magically create a sense of order, while the combination of some other elements only intensifies the visual chaos. The same pattern, the same colour, or even a few simple lines can inspire very different visual feelings in the eyes of different viewers. This makes the author very curious and confused, so the author began to observe these situations, fortunately due to the author's major reasons, there are a large number of cases can be provided to the author as a reference, the author found that there is a certain difference in people's visual cognition, the same set of graphics will be among different people there are certain differences, these differences are partly out of experience, partly out of cognition. Here is an example: for example, a designer prefers to use red and blue in combination, and over time his experience of red and blue has become a group, or a set of series, which seems to have no law, but may be through a certain algorithm can be derived from the law, which is the limitations and differences in experience and cognition.

Figure 4: "Order of Disorder" Web Interactive Installation

Based on these observations, the author have come to the view that people's understanding of visual order may be limited, and that this limitation does not stem from a narrowness of knowledge or insight, but is rooted in the inherent limitations of our physiological perceptions. People's perception of order is influenced by a variety of factors, such as personal experience, habits, cognitive styles, and viewing perspectives. Further, individual differences can also lead to different interpretations and effects on the perception of order.

From this perspective, order can be viewed as a selective concern and interpretation of disorder. Due to cognitive limitations, people may not be able to fully understand or perceive the regularities that occur during a particular period of time, thus giving rise to so-called 'disorder' (This concept is summarised by the author through the related research section). Thus, the author(The author here refers to me, and in this essay, all authors basically refer to myself.) argue that disorder is nothing more than flawed order - an order that cannot be fully interpreted within the limited cognitive framework of people. In exploring this concept, the author is not only studying how visual elements construct order, but also reflecting on and expanding people's understanding of the nature of order.

In the process of exploring visual order, the author stumbles upon the phenomenon of moiré, a kind of transition between order and disorder based on differences in visual perception. This phenomenon coincides with the author's thoughts on the concept of "order in disorder", which led to the creation of this interactive installation.

Inspired by the Moire effect, the "Order in Disorder" installation is based on a random dot matrix that allows the user to rotate the dots through mouse interaction. The dots overlap each other at different angles, creating new patterns and visual effects. These ever-changing patterns are not only an artistic expression, but also a source of experimental data to study the mechanisms of visual order.

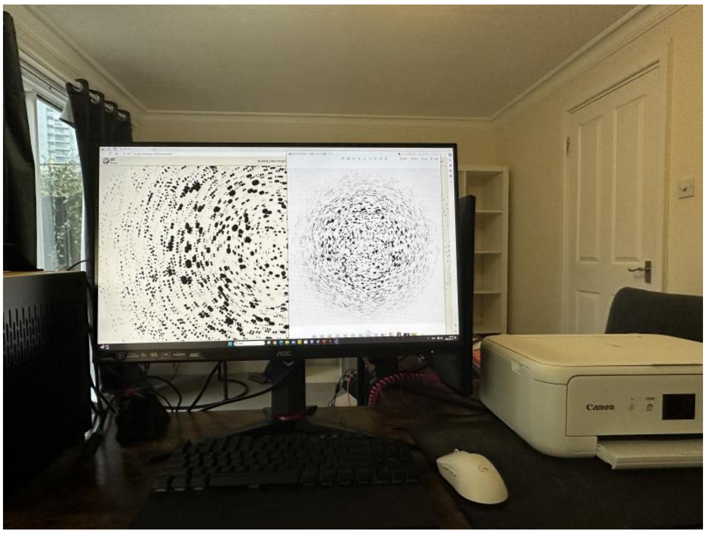

Figure 5:Users can download the finalised image after interacting with the device

Overall, the core objective of this interactive installation is to provide a rich data set for the author's research. It is not only a piece of installation art, but also serves as a research tool, providing an empirical basis for subsequent investigations into the causes and nature of visual order. By interacting with it, the user participates in a dynamic process of order creation, which in itself is a visualisation and scientific exploration of the idea of "order in order".

V.II Elements and Guides

Every artistic work is composed of various elements that are designed to shape a specific atmosphere and sensation; the complexity of which depends on the creator's intentions. In the interactive installation "Order in Chaos," the use of elements is extremely minimalistic, with the core simply being a matrix of dots for composition.

Figure 6: The overall visual style of the installation interactive page (1)

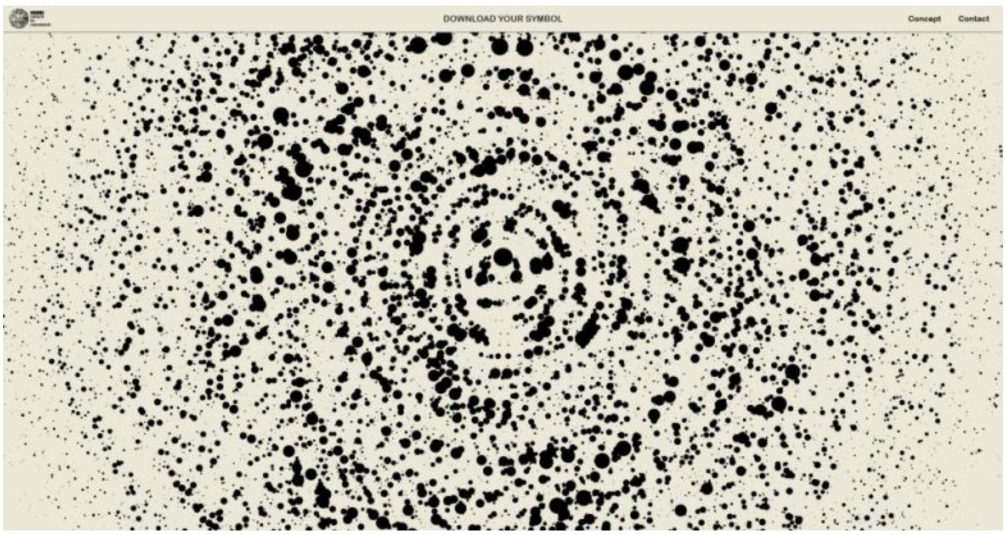

Figure 7: The overall visual style of the installation interactive page (2)

The creator adheres to a principle of simplicity because the piece is regarded as a natural experiment aimed at minimizing the interference of additional elements and guidance, allowing the individual experiences of participants to emerge organically.

As discussed in the section on "Visual Order," the concept of "visual attention" suggests that the visual effects elicited by an unconscious interaction with the pattern can more purely reveal the fundamental reasons for the formation of visual order in a natural state. Indeed, research indicates that when participants are clearly informed of the objective, they tend to identify order within patterns more swiftly; however, under natural conditions without explicit instructions, some subjects were unable to discern any discernible regularity in the patterns.

V.III Interactions

In the field of interactive installation design, the variety of means of interaction makes it difficult to accurately measure their strengths and weaknesses. However, the most appropriate means of interaction must fit the tone of the work. The design concept follows the principle of "Order in Disorder" and adopts a minimalist style, aiming to minimise human intervention on the participants, thus making the installation a more natural interactive experience (The author believes that the complexity of the artwork and the complexity of the interaction should be decided based on the concept of the artwork, such as Camella D. Kim's "no losers" or Joon Moon's "Augmented Shadow : Inside" which are not so complex but they bring a deep feeling to the audience. The author believes that this way of interaction is more "sincere" with the viewer, allowing the viewer to feel the work and its concepts more intuitively, and that it is closer to the viewer than complex interaction methods). For this reason, the design should focus on the balance between vision and movement, and simplify the user's visual and movement interactions while minimising human guidance, which is undoubtedly the most ideal path. In terms of specific interactions, touch and joystick interactions are complemented by the concept of rotation.

Touch interaction, with the advantage of being intuitive and fast, is controlled by the user's direct touch, which requires us to fine-tune the interaction experience of the device, especially in terms of comfort, although this may have an impact on the overall logic of the device.

In contrast, joystick interaction presents a simpler logic, where the user only needs to rotate the joystick to interact with the interface. However, joystick interaction has inherent limitations, for example, the limited operating range of the joystick does not provide fast and accurate positioning, and the vectorial information output from the joystick is not sufficiently precise to locate the target compared to a mouse. In addition, joysticks cannot select options outside of the interaction interface, and their cursors may cause abrupt jumps during sliding.

Considering the various scenarios, keyboard-mouse interactions demonstrate unique advantages on several levels. While the keyboard is similar to the joystick in terms of operability, the introduction of the mouse greatly expands the level and efficiency of the interface. The hovering feature of the mouse allows the user to break directly through the interface hierarchy and achieve rapid positioning, which is unmatched by the joystick in terms of speed. The precision and speed of the mouse further transforms the entire display area into a potential interactive space, where a large amount of information and interactive elements can be displayed unobstructed. The precision of the mouse reduces the likelihood of mis-touching, allowing the interactive elements to be designed more finely, thus increasing the density of the information displayed. Hovering the mouse cursor is equivalent to adding a new level of interaction, allowing auxiliary information such as item details to be hidden, further optimising the display of content. Based on the above considerations, in order to maximise control, a keyboard and mouse were chosen as the main method of interaction for the installation "Order in Disorder".

V.IV Generation of Dots

The dot-matrix is the central element of this device, and its design and implementation is crucial as it plays a decisive role in the visualisation of the moiré effect. In Glass's (1969) classic study "Moiré Effect from Random Dots", he observed the resulting moiré phenomenon by the more primitive physical means of spraying black particles on white paper, then photocopying them on transparent paper and rotating and overlapping them to produce a random array of dots. He then photocopied and rotated transparent paper and overlapped it to create a random dot matrix, and observed the resulting moiré phenomenon. In contrast, Barlow and Berry (2010) took a more systematic approach. They used a specific formula (shown in Figures 2 and 3) to generate random dot patterns and varied the density of the patterns by adjusting the parameters. However, the visual effects generated by this method did not meet my expected standards. Therefore, in terms of theoretical construction, I preferred to follow the experimental ideas of Glass (1969) but modernised and transformed them into an algorithmic form, aiming to digitally reproduce that original, randomly generated visual aesthetic.

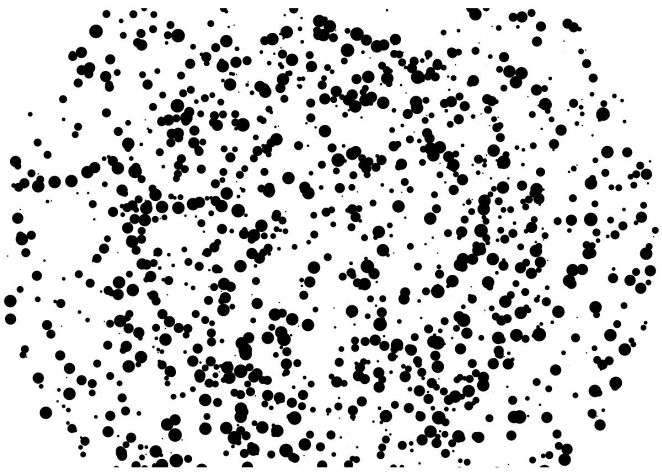

Figure 8: Random dot matrix generation test

Based on this concept, the author has employed the '<canvas>' element in conjunction with JavaScript classes to facilitate the generation and manipulation of interactive particles. The process of particle generation encompasses the following key steps: Initially, the total number of particles and the radius of the canvas (denoted as 'this.num' and 'this.canvasR', respectively) are determined. For each particle, a random radius ('radius') is generated using the 'getRandomRadius' function, which relies on the SmoothWeightRoundRobin algorithm to extract a smooth, weighted random number that dictates the size of the particle. This algorithm ensures the diversity of particle sizes while maintaining them within a predefined distribution range. Subsequently, the 'randomPoint' function, based on the center of the canvas and its radius, employs the method of transforming polar coordinates to Cartesian coordinates to randomly determine the coordinates (x, y) of the particles. Ultimately, these coordinates along with other parameters (such as color, center coordinates) are used to instantiate the 'Particle' class, and the created particle instances are stored in the 'this.spreads' array.

VI. Discussion and Future Work

Due to time constraints, and a number of unforeseen reasons, this research project attracted only 16 participants for testing, resulting in a small sample size. Nevertheless, by analysing these initial samples, we have been able to observe several signs of visual order formation, most of these participants seemed to recognise some kind of visual pattern, but based on personal differences (perhaps perceptual acuity, or reaction speed leading to individual differences in timing). Future research can continue on the basis of this sample to further refine the design of the interactive installation.

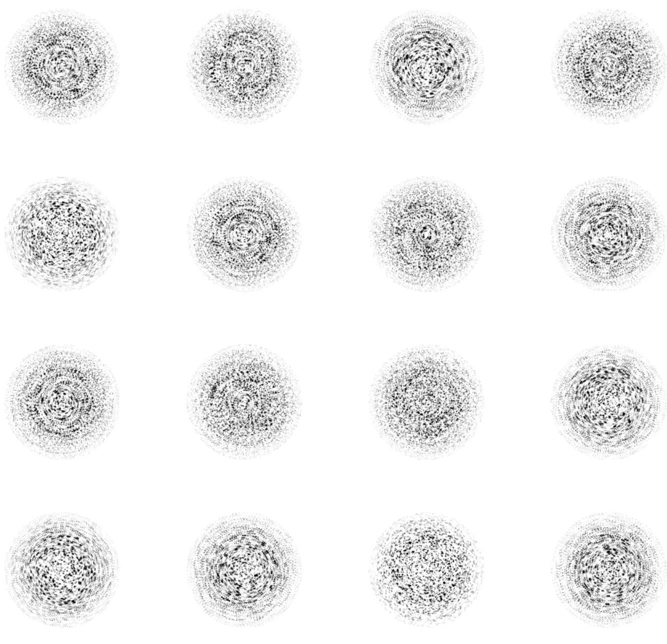

Figure 9:Final dot plot data for sixteen participants

From the 16 sets of data images shown in Figure 7, we can initially observe that most of the participants seem to recognise some kind of visual regularity. Despite individual differences in the time required for recognition (Figure 10), they were all eventually able to provide more structured feedback data.

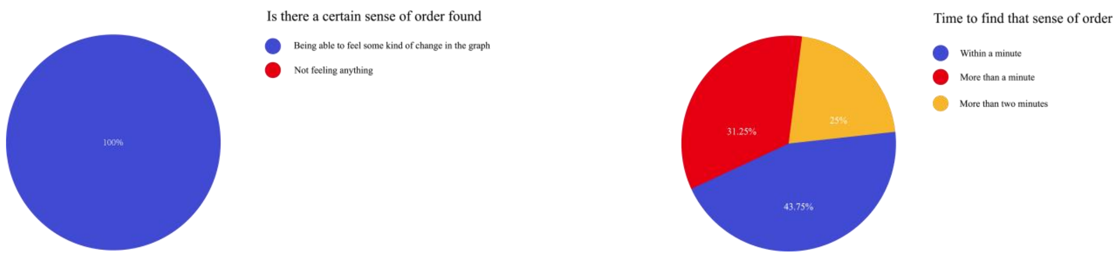

Figure 10: Experimental data feedback

There are certain visual commonalities in these data, in particular the presence of a large number of tangential edges allows us to acutely perceive changes in the graph. This leads to a further question: why are we unusually sensitive to graph edges? The reasons and mechanisms behind this phenomenon are worth exploring in depth.

Our heightened sensitivity to edges originates from the processing mechanisms within the visual cortex. Olshausen & Field (1996) discussed this issue, noting that the receptive fields of simple cells in the primary visual cortex of mammals can be characterized by spatial localization, orientation, and band-pass filtering (selectivity to structures at different spatial scales). To further understand this, we must introduce the concept of "visual stimuli," which primarily involves two pathways: the What-Pathway (ventral stream) and the How-Pathway (dorsal stream).

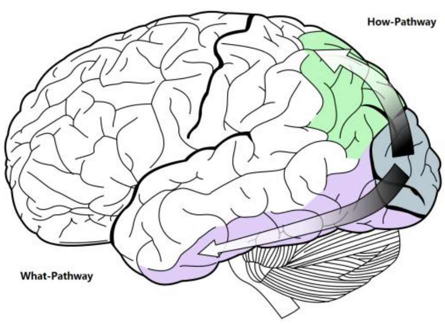

Figure 11:What-Pathway (Ventral Pathway) and How-Pathway (Dorsal Pathway) for Visual Cognition

The What-Pathway, as the name suggests, is concerned with object recognition — "what is this?" — while the How-Pathway is involved with the functional cognition of objects — "what can be done with this?" For instance, recognizing an object on the table as a cup is the function of the What-Pathway, and using the cup to drink water is the role of the How-Pathway.

So, how do we perceive the orderliness or chaos of things? Environmental factors and memory play key roles in this cognitive process. Thus, the cognition of orderliness is largely subjective. Although the above discussion outlines part of the visual cognition process, the cognitive processes in living organisms are far more complex. Cognition involves deep psychological manifestations such as sensation, perception, memory, and experience, followed by the processes of thinking, reasoning, imagining, understanding, and interpretation. Hence, comprehensively explaining the formation of orderliness is undeniably challenging(Yi, 2016).

From a more fundamental perspective, the edge definition of forms creates a specific visual stimulus. For the visual cortex, this acts like a "cocktail party effect," drawing our attention amid complexity and ultimately leading to cognition of the form. In essence, "order" is the result of our focused attention on "disorder," essentially a form of selective attention. This research could lead to more in-depth discussions, such as: "Is there a discernible pattern to this visual perception, and can it be visualized or quantified? How can we optimise the human visual system and can our natural system be more perfect?" Olshausen & Field (1997) explored similar issues in their research by studying the receptive fields of simple cells in the visual cortex, finding that these fields can be described as spatially localized, oriented, and band-pass, similar to the base functions of wavelet transforms. One approach to understanding the response characteristics of these visual neurons is to consider how they efficiently encode the statistical structure of natural images. Building on this concept, numerous studies have attempted to train unsupervised learning algorithms on natural images to develop receptive fields with similar properties.

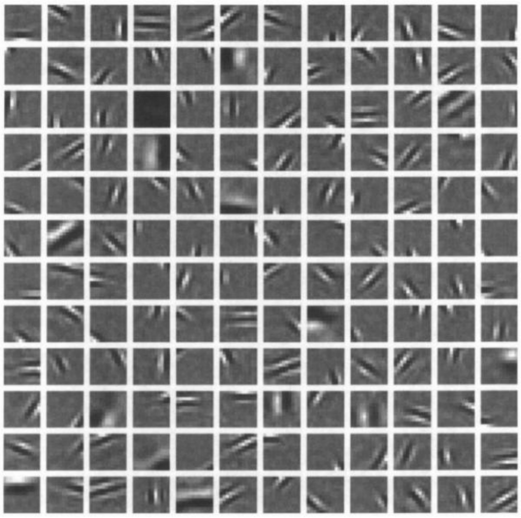

Figure 12: 144 basis functions of a sparse encoder trained from natural images by Olshausen & Field (1997)

Barlow & Berry (2010) have also used simulated systems in their experiments to find ideal systems in the visual system that have advantages over the natural system. Given the expansive nature of the topic, which intersects with numerous disciplinary fields and necessitates a comprehensive understanding of the involved knowledge, so this will be one of the possibilities for future research and author plan to explore and experiment further in the future based on the results of author's current research.

VII.Conclusion

This study documents the design concept, development process and key details of the web-based interactive installation "Order in Disorder". The report highlights key aspects of the design process, with particular emphasis on the design philosophy and conceptual framework. The data analysis reveals the high sensitivity of the human brain to visual order. Although there are temporal and individual differences in the perception of visual order, it is found that most people's visual system recognises order almost instantly, and this recognition process relies on specific visual stimuli. This response relies on specific visual stimuli. This finding is supported by studies such as Olshausen & Field (1996) and Barlow & Berry (2010). In addition, the author expressed a keen interest in how such visual stimuli are produced. Moiré, as an iconic visual pattern, creates a marginalising effect through rotation, which stimulates the viewer to perceive 'order'. The author hope to explore more possibilities of visual order in future research.

List of Illustrations

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