UNIVERSITY OF CALIFORNIA

SANTA CRUZ

Edges of Color

An exploration of colored light in a tech culture environment.

A thesis paper submitted in partial satisfaction
of the requirements for the degree of

Masters of Fine Arts
in
Digital Arts and New Media

by
David Harris
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ABSTRACT

Edges of Color is a platform for immersing viewers in an abstract color environment. It shows static or dynamic color patterns on an 8'x8' wall-mounted display of 256 4"-square color pixels, each of which can be nearly 17 million colors. The piece is an exploration of what is possible in colored light (in contrast to paint), along with a set of specific displayed pieces, with reference to the color paintings of Gerhard Richter, Damien Hirst, and others.

The piece is infused with the science, psychology, and perception of color, but presents as a contemplative experience, in which viewers are encouraged to stay and watch the display for an extended duration, able to enjoy the experience of intense and pure colors but also able to see beyond to the conceptual bases of the works by the presence of take-home information cards.

Initial pieces for the platform include: 1) *Random Richters*: a set of color swatches in the style of Richter's color charts, but with colors determined via a quantum random number generator; 2) *Unprintable Colors*: A display of the colors that can be shown in RGB light but that can not be printed in a CMYK four-color process; 3) *Pink Perceptions*: an exploration of the color science of pink, one of the few named colors that doesn't have a corresponding single wavelength of light, but exists only as a superposition of red and blue wavelengths; 4) *Colour Lovers*: a display of the most popular color palettes submitted by users at www.colourlovers.com; 5) *Every RGB Icon*: a remake of John F.

Simon's seminal digital art piece "Every Icon" but displaying every possible color icon instead of all black and white icons.

The thesis places this work in the context of the cultural and political climate of Silicon Valley in the 21st century, thereby asking questions about the limits of the processes of science and technology.

ACKNOWLEDGEMENTS

This project has been possible only with the assistance and guidance of a great number of people. In particular, Jennifer Parker encouraged me to tackle a more ambitious project than I might have initially, consistently asking probing questions that informed my aesthetic, design, and construction decisions. Soraya Murray not only taught me a lot of art history and theory, but pushed me to ask myself why I make the art I make and elicited something of an answer, quite revelatory to me, although I suspect that she might push me even further if given the chance. Adam W. Brown provided inspiration for what can be done at the science and art interface, and prompted me to find my own aesthetic.

Among my cohort, all of whom have been extremely supportive, Sean Pace helped me get over my fear of tools and building, and Zach Corse provided great intellectual stimulation from our shared interest and backgrounds in physics.

When I embarked on an MFA, at the encouragement of my wife, Danielle, I didn't necessarily know how much heavy lifting she would need to do, especially given that our first daughter was born mere months before I commenced. For giving me the chance and support to follow my passions, I am eternally grateful. Alexandra, though too young to understand what is happening, helped bring the project to a close that I rate as successful as possible because she was so entranced by the resulting piece, teaching me that art can work on many levels.

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1. Introduction

> "Mere color, unspoiled by meaning, and unallied with definite form, can speak to the soul in a thousand different ways." - Oscar Wilde

Color and technology currently have a difficult relationship. Not only is the technology of color complicated and arcane, as evidenced by the multiplicity of color settings required to calibrate software to a monitor to a printer to true colors, but some technology doesn't work well, leading to unfortunate circumstances such as where Hewlett Packard computer face tracking software would recognize white faces but not black ones (Frucci 2009). Color remains a concept open for exploration, partly because it is so present in our semiological environment that is near invisible for most of us due to its ubiquity, and challenging for those who experience color blindness.

Color and light are foundational components of visual art that have been explicitly explored in depth over many centuries. However, the limits of color presentation have not been completely determined in the visual arts, especially when taking into account that emitted light with additive mixing (typically defined by red, green, and blue components) has different characteristics from reflected light with subtractive mixing (typically defined in modern contexts by cyan, magenta, yellow, and black components).

In a technoscientific age, art is often inspired, but also limited or directed, by commercially available technologies, which have their own problematic issues and

concerns. My work comes from a place embedded in this technoscientific culture, but responds to it by pushing the limits of that visual culture from within that culture. By seeking the boundaries of what is possible in color light display, issues of conformity and creativity in a Silicon Valley environment are the subjects of investigation.

In her recent book *Chromatic Algorithms: Synthetic Color, Computer Art, and Aesthetics after Code*, Carolyn Kane argues that it is vital to "understand the ways [color] has played a pivotal yet unacknowledged role in the material development of contemporary aesthetics and the history of new media art." (Kane 2014, 19)

This paper begins with a description of the "color display" platform, instantiated as *Edges of Color* (2016), and the pieces to be displayed. Then the work will be positioned in a lineage of color-based art placing the color display in conversation with artists such as Gerhard Richter, Damien Hirst, Jason Salavon, Jim Campbell, and others. After this artistic contextualization, the work will be discussed in cultural and political terms, with an investigation of how it creates meaning through its abstract form.

2. The color display

The “color display” is an 8’x8’ wall-mounted installation that shows 256 (16x16) pixels of color. Each pixel is 4”x4”, separated from the next by a 1 ¼” strip. The pixels are individually controllable and can display any color in 24-bit resolution, i.e. from a palette of 256x256x256=16,777,216 colors. Note that the “web safe” palette consist of a mere 216 colors, although most computer monitors can show a significant fraction of the 17 million RGB colors.

The overall aesthetic is of paper and cardboard, in contrast to the usual colder, metal, wire, and acrylic or glass that is typically used in light art installations. Reasons for this choice will become apparent later in the paper when the meanings created by the piece are discussed. The support frame is made of wood covered in a layer of cardboard with a cardboard spacer array, cardboard diffuser layer and black paper. Each pixel then is, in essence, a set of nine RGB LEDs housed in a separate 4”x4”x1.5” box covered in a diffusing sheet of semi-translucent tracing paper (**Error! Reference source not found.**).

The display was mounted against a wall in a darkened, enclosed space, with accompanying furniture including a couch to encourage viewers to spend time contemplating the piece and a side table with information cards that helped viewers determine which specific piece was being displayed at any moment and gave some theoretical or informational context for the piece (Figure 2).

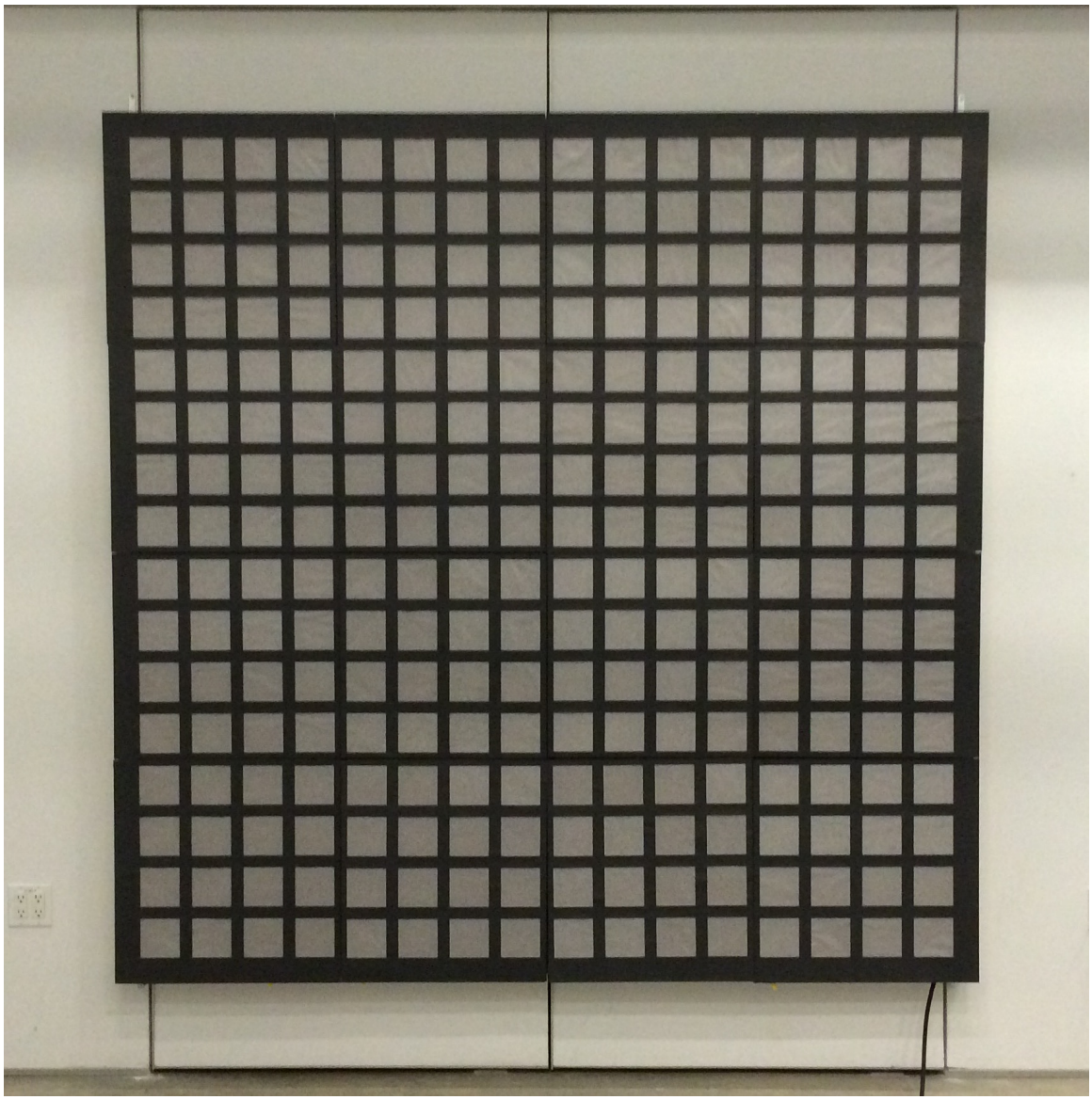


Figure 1: The color display turned off to show finished form.

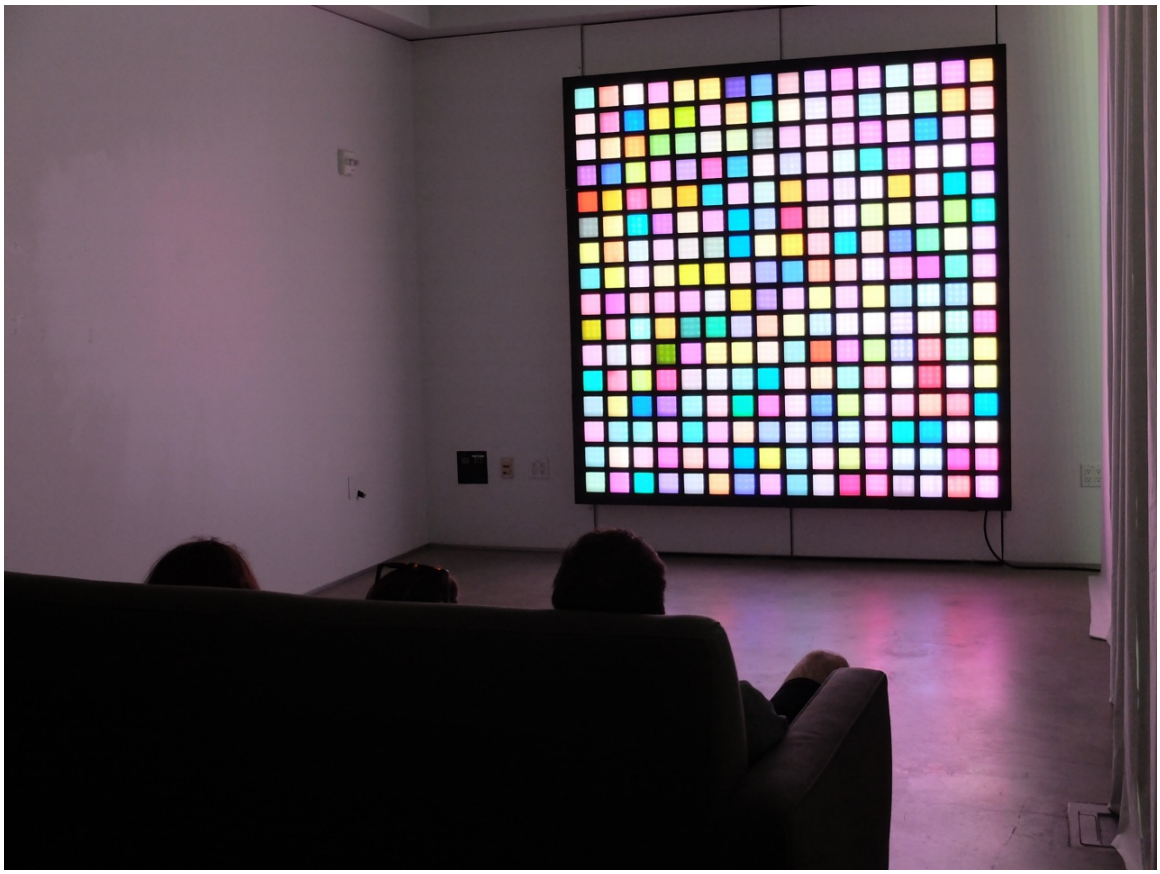


Figure 2: Viewers contemplate the *Edges of Color* piece at the UCSC MFA show exhibition in May 2016.

The color display, which will often be referred to as the “platform” for the work of “pieces” displayed on it, showed a sequence of five color works.

It is important to properly define what I mean by “platform” in this context as it has a variety of meanings in the art/computing/new media worlds. Using a definition from the worlds of engineering, design, and business management, Lane Relyea describes their definition of a platform as “a basic, underlying architecture or system, a common workbench that, while stable and enduring, is open and flexible enough to allow for a high variety of interfaces, a range of inputs and outputs.” (Relyea 2013)

Relyea also distinguishes platforms from other architectures by their “looseness”. He writes, “Rather than bounded and fixed, they are traversable, permeable, and responsive, constituted by dialogue with an outside. Whatever profile or boundary they do possess is only the one their interfaces actively conjure.”

Olga Goriunova adopts a slightly different definition of platform based more on the political implications of the term since it was adopted in seventeenth-century England. She writes that since that time, “‘platform’ has generally meant a set of shared resources that might be material, organizational, or intentional that inscribe certain practices and approaches in order to develop collaboration, production, and the capacity to generate change.” (Goriunova 2012, 8)

She goes on to define an “art platform” as having, and often centering around,

> "a database, structured in a variety of ways, that users can upload to (sometimes with sets of restrictions applied, such as filtering), download from, or browse through (again sometimes with filtering) and sets of functions centered around this activity, such as voting, ranking, featuring, commenting, and others." (Goriunova 2012, 9)

This latter definition is more applicable to Web 2.0-based sites rather than the more general definition of platform I am using, which is closer to Relyea's.

Of particular note is the idea that platforms not only have limits but also implicitly encourage certain kinds of use, in whatever definition is generally used. Specifically, my platform "encourages" the display of images or video, made up of pixels, as it is. However, part of the purpose of this piece is to approach the platform with a view to seeing what else can be done with it, beyond the obvious, or the encouraged.

A selection of pieces

The following five pieces are works that I have designed for the color display, to explore some possible themes enabled by the platform. In this section, I present a brief description of each piece. Later in the paper, the pieces will be called out individually to illustrate historical, cultural, and political themes.

1. Random Richters

Some of renowned German artist Gerhard Richter's color swatch works were ostensibly made of randomly chosen paint colors. However, the human mind is extremely poor at generating or recognizing random sequences in any form. The *Random Richters* piece

shows an ever-evolving truly random selection of colored pixels, with the randomness generated by quantum mechanical physical processes.

2. Unprintable Colors

A little known fact is that the range of colors that can be displayed via standard CMYK four-color printing processes and colors displayed as RGB light mixtures are not the same. There are "off-gamut" colors that can't be displayed in a particular form. *Unprintable Colors* explores the color space that is off-gamut to CMYK printing.

3. Pink Perceptions

Pink is one of the few named colors that do not have corresponding single wavelengths of light associated with them and it is also one of the most emotionally charged colors in Western culture due to its common association with femininity, and a color not often chosen for hardware or software display in the male-dominated Silicon Valley culture. Most colors can be represented as a single wavelength, or frequency, chosen from the optical spectrum, most commonly represented in a physical rainbow. Pink exists only as a mixture of red and blue wavelengths and is observed by the brain as a mixture of the signals picked by up red and blue color receptors in the eye. *Pink Perceptions* dynamically morphs between red and blue via pink in a slowly changing color sequence that activates the eye's color receptors in turn and in combination.

Figure 3: ***Random Richters*** **(2016), David Harris**

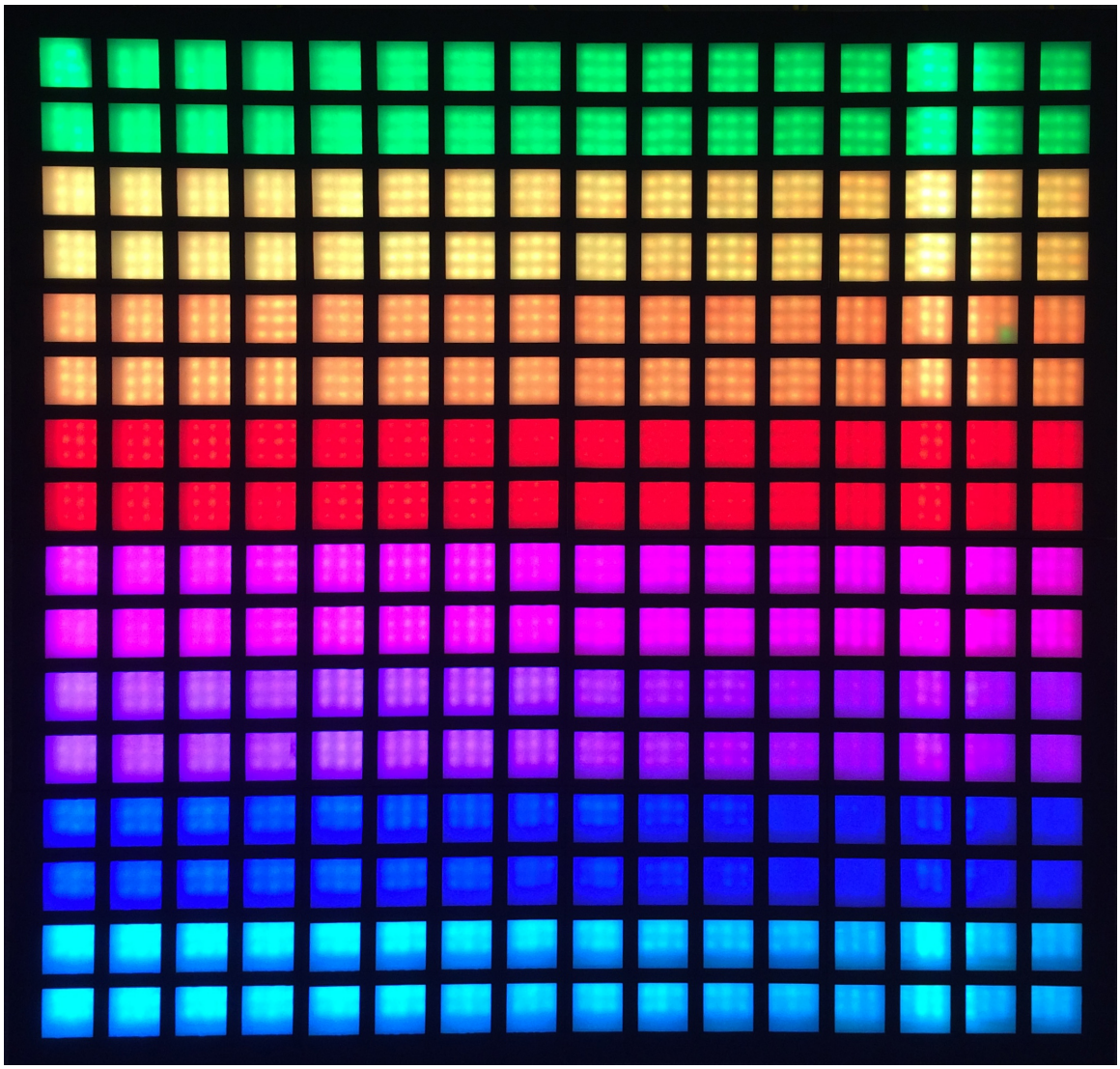


Figure 4: ***Unprintable Colors*** **(2016), David Harris**

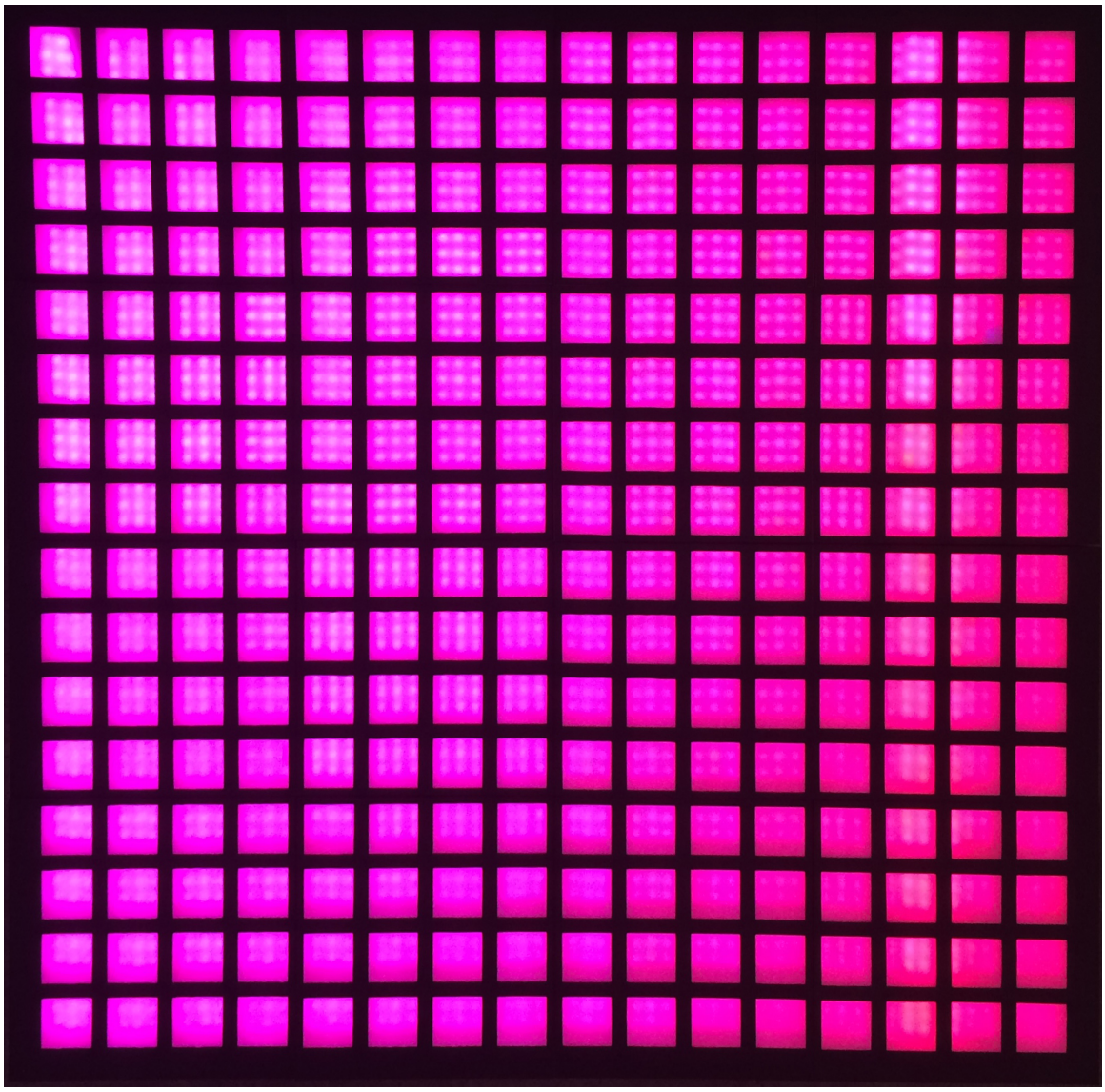


Figure 5: ***Pink Perceptions*** **(2016), David Harris**

4. Colour Lovers

People develop strong emotional reactions to color and color combinations even to the point of them expressing "ownership" of colors or color palettes. Some of these are most readily observed on the www.colourlovers.com website. *Colour Lovers* shows the most-loved color palettes, as created by and voted on by users of the colourlovers.com site. Users develop reputations and rankings based on their contributions to the site and some clearly spend a great deal of time in the world of color. The *Colour Lovers* piece shows the five most-loved palettes of all time. The top piece is created and named "Giant Goldfish" by user manekineko. It consists of two custom colors by manekineko along with three colors defined by other users. Manekineko has over 3000 followers who are notified of his new colors and palettes. Although the users who created the colors and palettes are credited, the terms of colourlovers.com states that it has an irrevocable right to use the user-generated content as it wishes, thereby employing a tactic of most modern web platforms, that of acquiring effective unpaid ownership of user content.

An interesting feature of the *Colour Lovers* piece is that it provides a workspace for testing the color theories of German-American artist and educator Josef Albers (1963) and others. The sets of three identical lines of color appear to differ within the three as they are influenced by the colors above and below, with colors appearing either lighter or darker than the central of the three lines depending on the adjacent color. This optical illusion is not especially present in the reproduction of the piece (Figure 6) but is quite strong when looking at the display in person.

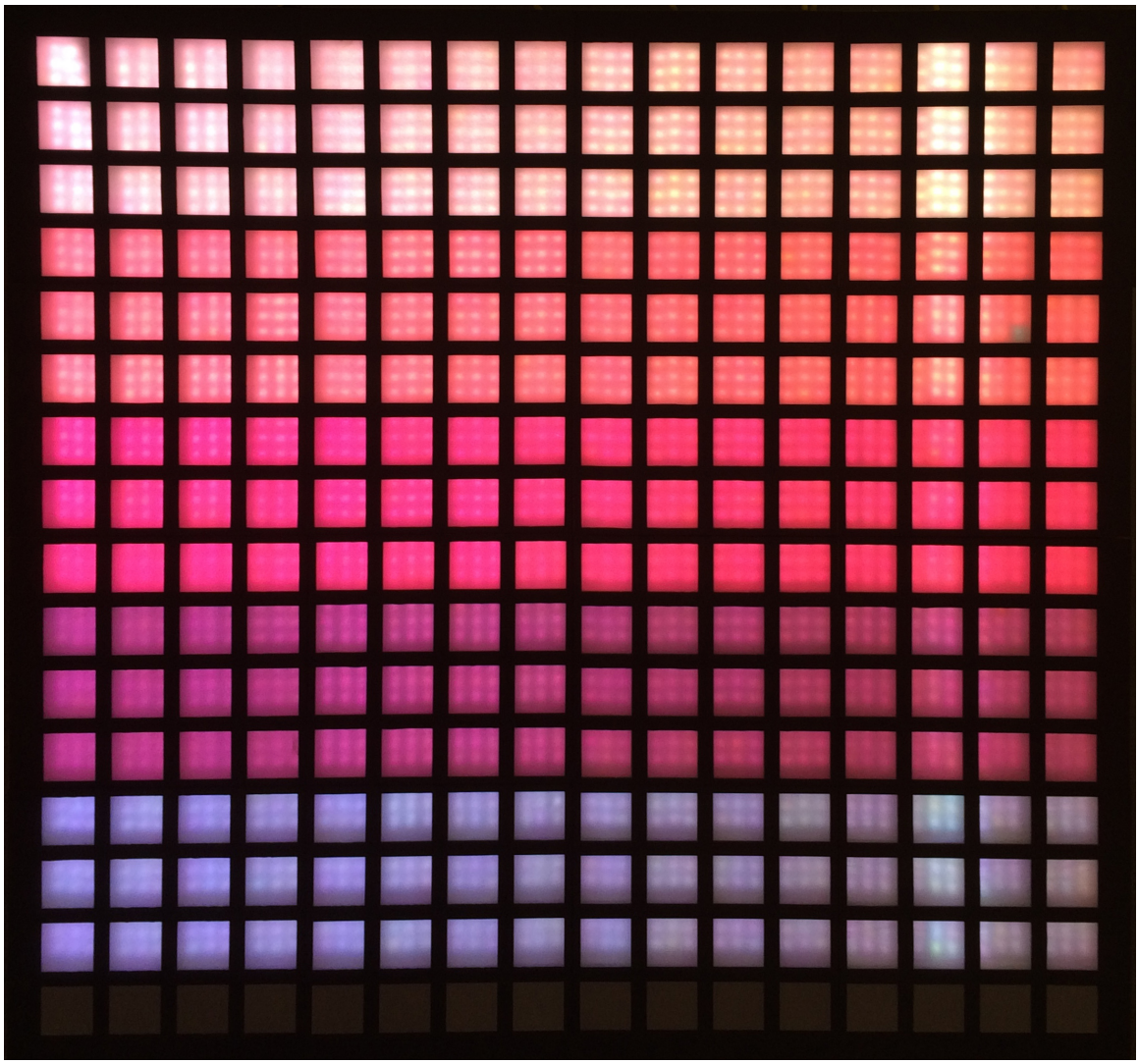


Figure 6: ***Colour Lovers*** **(2016), David Harris**

5. Every RGB Icon

A landmark digital media artwork is John F. Simon Jr.'s *Every Icon,* which, by the process of binary enumeration, generates every possible black and white icon. *Every RGB Icon* recreated the theme of this work but by showing every possible colored icon in a 16x16 grid. Instead of each pixel have one of two values in Simon's work, the color version has each pixel taking one of more than 16 million values. The total running time of this enumeration is so long that even the lifetime of the universe so far (~13.7 billion years) is minuscule in comparison. In fact, if the piece started running at the time of the Big Bang 13.8 million years ago, it would still be part way through the first of the 16 rows on the display. The power of exponential growth is so unfathomable to human minds that numbers and times on this scale are beyond any kind of true human comprehension or timescale. This piece alone shows that the potential of color investigation is so vast that it goes beyond what humans can fully consciously comprehend.

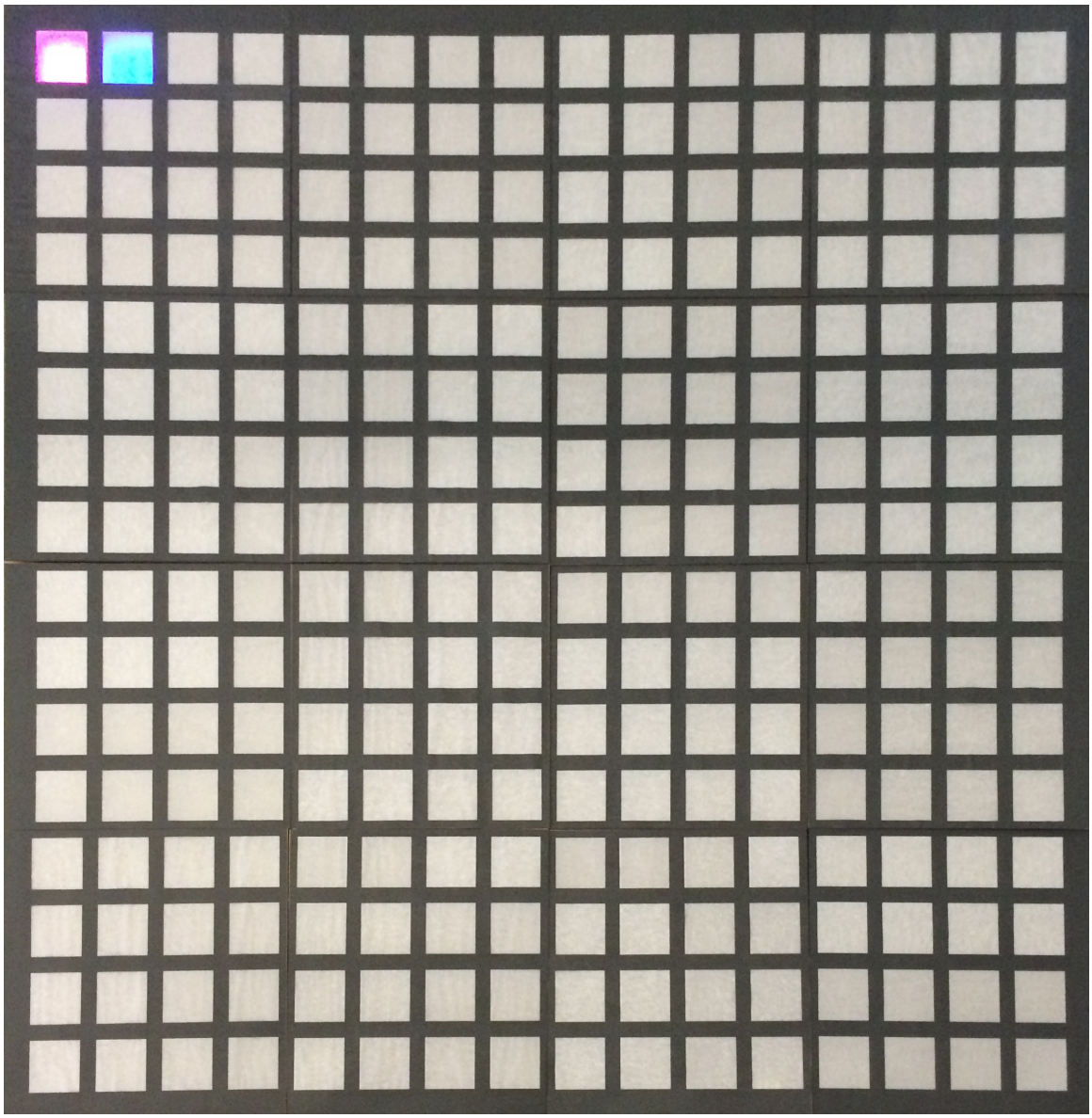


Figure 7: ***Every RGB Icon*** **(2016), David Harris**

Open sourcing the work and a call for artists

Part of the Silicon Valley culture, in which this piece is produced, is a strong call for the open-sourcing of creative work. This is a problematic position in many ways as there is usually somebody taking commercial advantage of most open-sourcing efforts. After much deliberation, I have decided not to open-source the designs and programming of the color display as the current terms under which it is typically done serve to reinforce a culture of commercial appropriation of individuals' works.

As part of the future development of this project, I will be announcing an open call for artists to present works on the display compatible with the aims of exploring the boundaries of color in light. This will be advertised through various digital media mailing lists and venues.

A future exhibition of the work could include a series of pieces contributed by artists from around the world, coming together to form more color exploration or other uses of the color display. One such contribution has already been suggested by Andrea Steves and Timothy Furstnau of FICTILIS, in which the display would show a series of copyrighted colors such as Ferrari red and Susan G. Komen pink.

3. Artistic influences

In the following section, I look in some detail at the artistic influences informing the creation of the color display platform and the pieces displayed on it.

Richter's color charts

Gerhard Richter (b. 1932) is a German visual artist who has achieved great prominence in the contemporary art scene, with his painting achieving record prices for a living painter at auction in recent years. His work has moved through multiple phases, employing different media and styles. The styles have included abstract color field images, photo-realistic paintings, and glass sculptures.

Richter painted a few series of color charts from 1966 to 2008 that were similar in form but varied in motivation and planning. The earliest color charts were simply rectangular blocks of color on a white background, with colors derived from commercial color charts then available (Figure 8). As Richter developed the form, the paintings started to involve more swatches of color, and some process behind the color choices. His color charts grew in complexity and size, culminating in his piece with 4096 color fields in 1974 (Figure 9). He then rebooted the series in 2007, perhaps inspired by his 1989 *Glasfenster, 625 Farben*, and his 2007 colored-glass work for a cathedral in Cologne, Germany (Figure 10).

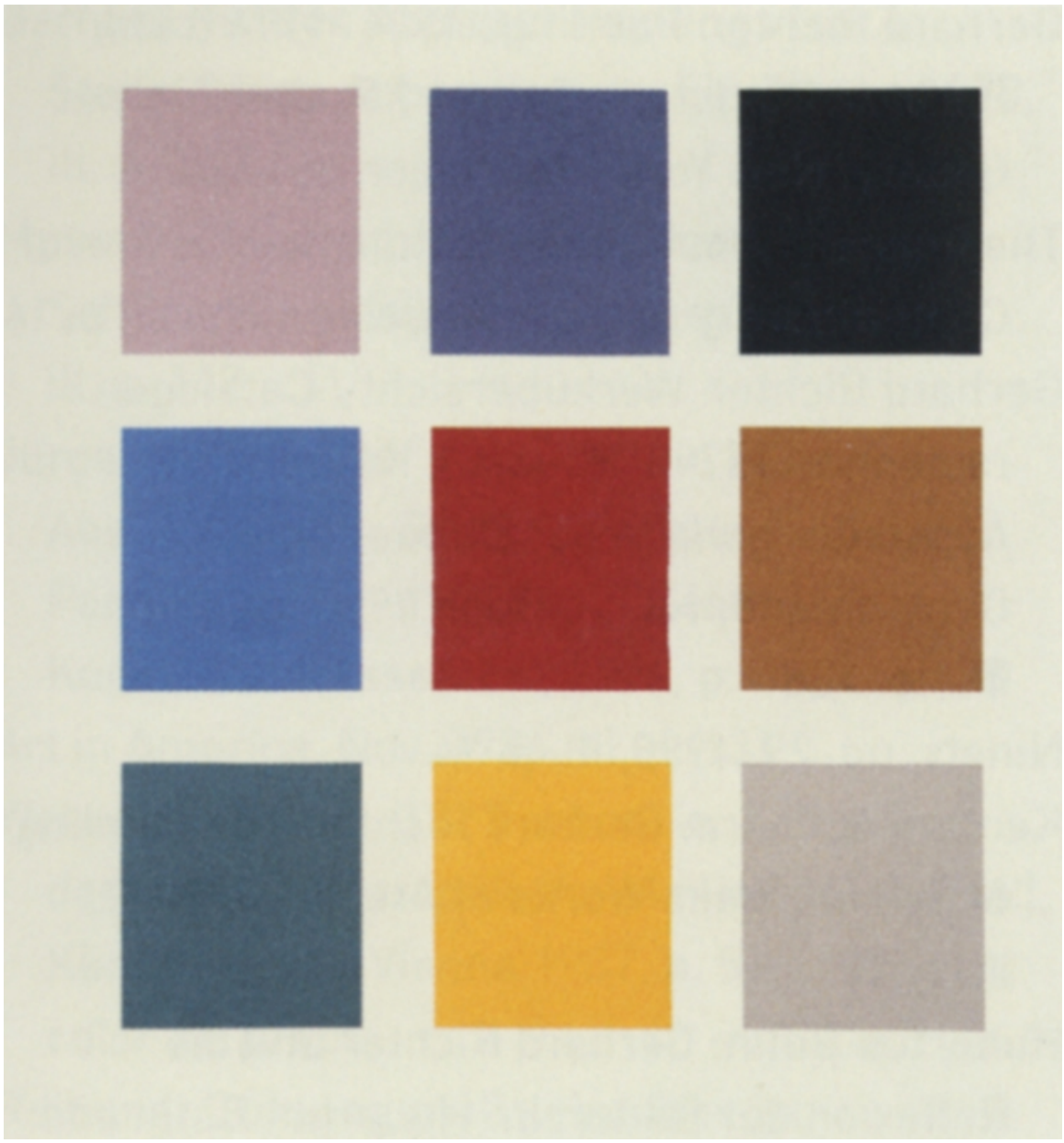


Figure 8: ***Farbtafel*** **(1966), Gerhard Richter**

Figure 9: ***4096 Farben*** **(1974), Gerhard Richter**

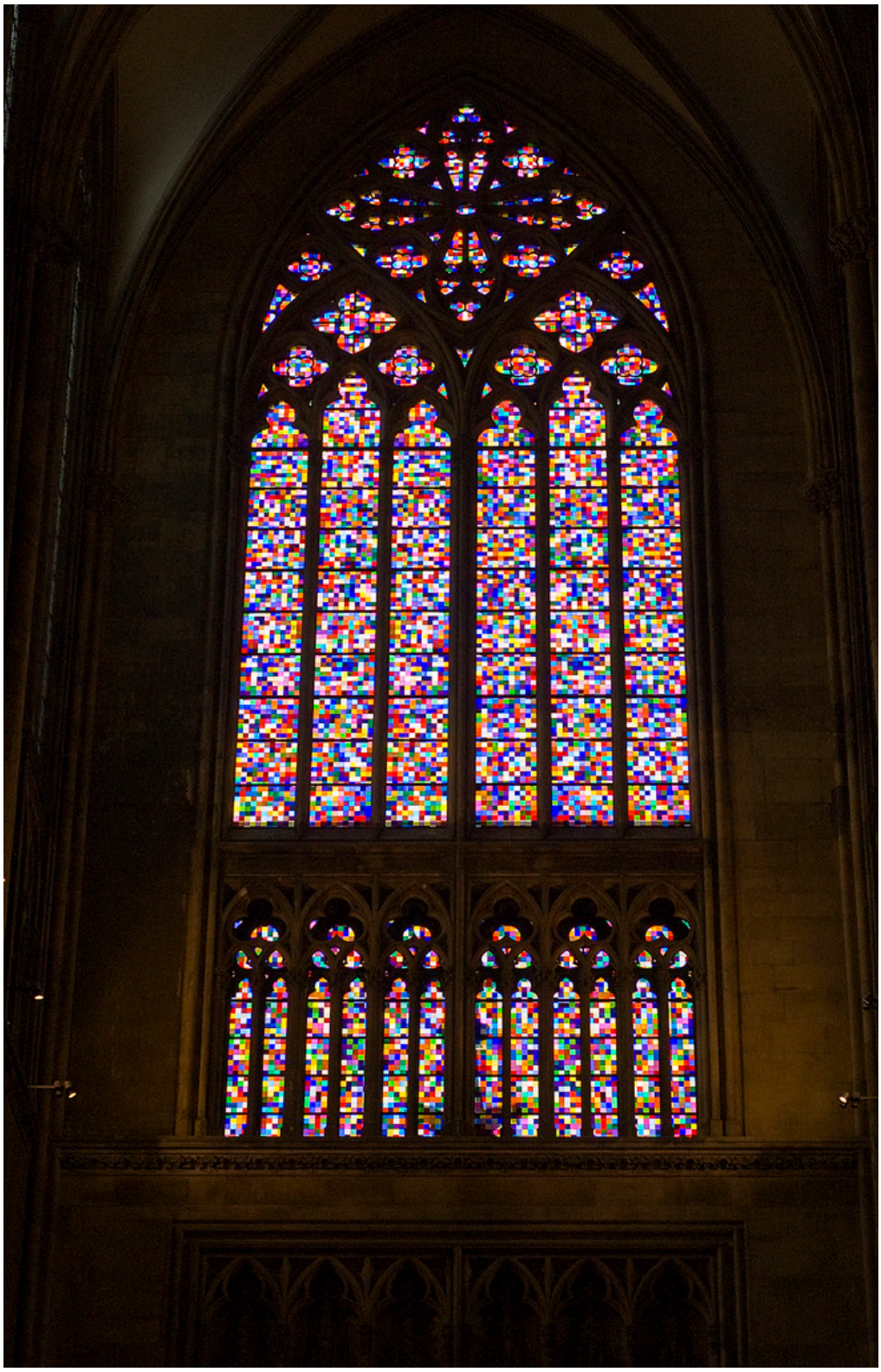


Figure 10: Window in Cologne Cathedral (2007), Gerhard Richter

Whereas Richter's color charts were all executed in paint, his interest in photography and light were central to his experiments and explorations of painting. My work on this platform re-creates some of those experiments using pure light, rather than paint, to bring attention to the differences inherent in those media.

Writing in 1973, Richter stated, "The first colour charts were unsystematic. They were based directly on commercial colour samples." (Richter 2009, 82) Richter essentially took color chart samples, and painted grids of them, albeit in random orders. The pieces were heavily influenced by Pop Art and the concept of readymades, where his colors were readily available commercial paints.

In the next series of color charts, in 1971, his work took a more conceptual turn and he experimented with using a rule-based selection of tones. His *180 Farben* pieces used tones mixed according to rules but then placed in a random order. Richter wrote of this second series of paintings,

> "In the canvases that followed, the colors were chosen arbitrarily and drawn by chance. Then 180 tones were mixed according to a given system and drawn by chance to make four variations of 180 tones. But after that the number 180 seemed too arbitrary to me, so I developed a system based on a number of rigorously defined tones and proportions." (82)

Taking this to its logical conclusion, he wrote in 1974 that

> "In order to represent all extant color shades in one painting, I worked out a system which—starting from the three primaries, plus grey—made possible a continual subdivision (differentiation) through equal gradations." (91)

Those colors were then placed in random order.

Curiously, the *1024 Farben* series does not appear to just include tones of the primaries and grey, but also includes greens. In 2006, he described the process slightly differently, "The starting point are the four pure colours red, yellow, green and blue; their in-between shades and scales of brightness result in color schemes containing 16, 64, 256, and 1,024 shades." (517)

He also commented, "To use more than 1,024 tones (4,096, for instance) seemed pointless, since the difference between one shade and the next would no longer have been detectable." (91) Each of the four elements of this set of paintings used the same colors but in different permutations. Richter was fascinated by the fact that "if I had painted all the possible permutations, light would have taken more than 400 billion years to travel from the first painting to the last." (91)

One painting in the series did, in fact, use 4096 color panels, but it was done by using 4 repeats of each of the 1024 colors in the previous pieces. This piece consisted of squares of color abutting each other rather than the rectangles on white of most of his previous color charts.

Richter abandoned the color charts until 2007 when he recommenced a series that only included colored squares abutting each other, in his two series *25 Farben* and *Quattro Colori*. These might have been aesthetically inspired by a piece he developed for a cathedral in Cambridge, UK. (Figure 9) In 2006, Richter wrote,

> "In early 2002, the master builder of the cathedral suggested that I develop a glass design for the southern window….After several unsuccessful attempts to get to grips with the subject, and prepared to finally concede failure, I happened upon a large representation of my painting with 4,096 colours…. All in all, the glass work will be made up of 11,000 squares measuring 94x94 millimetres each. Half of these (i.e. 5,500) will be allowed by means of a random generator, the others will be like a mirror image of the ones randomly allocated." (518)

Although the randomness of these works was inherent in the concept of the pieces, Richter stepped back from overstating the significance of randomness in a 1974 interview. When asked why the colors were arranged randomly, he replied, "Because I can't imagine a better or more appropriate order—but that already sounds too laden with importance, as if I were aiming to present a random order. I just want to make a painting." (90)

RGB Richters

My project clearly draws heavily on Richter's work but extends it in various ways, specifically in terms of new technology, displayable colors, and randomness. Richter said in 1964 that, "The central problem in my painting is light." (35) This is partly a reference to Richter's extreme rationalization of process. He states that he produces his paintings without "apprehending" the images in the photographs he reproduces. Richter says that

he is loath to convey meaning for his pieces through language, as there is no point: “You construct qualities that can be said, and you leave out the ones that can’t be said but are always the most important.” (35) And so, he lets light play its role in vision: Where light created the photographs he painted from, light also illuminates his paintings and makes them visible to the viewer.

My piece takes that problem of light and illumination to heart and tackles the questions posed by color choice and display in the format of pure light rather than reflected light from paintings. In my piece, there is no reflected light from an image. The image is made directly on the retina, much as a camera captures an image directly in Richter’s view. Whereas Richter saw the photograph as the most perfect representation of an object, my piece removes the intermediary of a photograph, or indeed of his paintings of photographs, and creates an image for the viewers directly as a sensory stimulation of their retinas. It is an image that cannot be perfectly reproduced as it relies on color generation in light (which cannot be reproduced in print, as discussed below) and the physiological process of color reception on the retina.

Working with RGB LEDs means working in the color space of additive primary colors (red, green, and blue) rather than subtractive primary colors (red, yellow, and blue). This technological choice has a few subtle but important effects on the color charts displayed. For example, the gamut (or range of colors) that can be painted in a subtractive system extended to a standard four-color CMYK (cyan, magenta, yellow, black) gamut covers a wide range of colors but does not include all colors that can be generated in an additive

light system based on RGB LEDs. Conversely, some CMYK colors cannot be represented in the RGB gamut. These out-of-gamut colors are explored in *Unprintable Colors*.

Working in reference to Richter's earliest color charts, another piece shown on the color display consisted of "pleasing" color chart combinations based on the "most loved" lists of colors at www.colourlovers.com/palettes. However, these color charts are created in raw form as digital light palettes, rather than paint palettes.

Randomness played a large role in Richter's color charts. The human mind is extremely poor at either generating or recognizing truly random sequences. Truly random color sequences would appear to have repeated similar colors more often than expected, and missing colors more often than expected. Conversely, human-generated "random" sequences will tend to include more colors and less repetition of those colors. This is comparable to a human writing down a random string of heads and tails resulting from coin tosses. A human string will rarely contain sufficient subsequences like "HHHH" as the repetition feels like it isn't random but probability theory predicts that such subsequences comparable to this should actually be quite frequent. In fact, light artist Jim Campbell says that when he generates random sequences he then goes in and modifies them to remove clumping and spacing to make the sequences or patterns seem more random even though it is actually reducing randomness (Campbell 2016).

Richter himself captured this sentiment in 1964, writing, "It is hard, say, to cross out six

different numbers on a Lotto ticket in such a way that the arrangement looks convincing. And yet the sequence that emerges after the numbers are drawn seems entirely right and credible in every way." (21)

Generating random numbers is an entire field of research in mathematics, computer science, and physics. However, physical law suggests that the only place true randomness can come from is quantum physics. All other techniques used for generating sequences will merely be pseudorandom.

One physical technique for generating random sequences, then, comes from examining the quantum noise inherent in the operation of a laser. Such a system has been implemented at the Australian National University, where the resulting random bit strings are available over the Web at http://qrng.anu.edu.au/ using an API (Application Programming Interface).

My *Random Richters* piece draws random numbers from the ANU server, using each eight-bit string of 0s and 1s to generate the 256-level color intensity of each of red, green, and blue LED illumination, thereby generating one random element of the set of 16,777,216 colors capable of being displayed in each pixel of the RGB LED system used in the platform. Following Richter's argument, using more colors and finer gradations will not be appreciable to the human eye and are not employed here. More colors could, in principle, be generated with a different electronic schema but to little additional effect.

Richter's work provides a foundation for exploring the nature of color in the digital additive color space rather than the analog subtractive color space. My work re-creates Richter's experiments in color using the latest color technologies and then move on to show the distinctions between paint and light for the purposes of displaying color.

Damien Hirst's spot paintings

Damien Hirst (b. 1965) is an artist and collector who rose to fame in the 1990s as one of the Young British Artists (YBAs), many of whom had graduated from Goldsmiths in the 1980s. He is perhaps best known for his vitrines of halved animals and his process involving assistants executing his ideas, often in multiple instantiations.

Hirst completed eleven series of spot paintings from 1986 to 2001, with color spot arrangements ranging from 25,781 one-millimeter spots (*L-Isoleucinol* (2008 – 2011) (Figure 11)) to four 60-inch spots (*Erbium Oxide* (2009)). There are over 1000 spot paintings in existence and over 300 of them were collected in an exhibition spread across 11 galleries in 2012. He has named many of the spot paintings by using the chemical names of drugs from chemical company Sigma-Aldrich's catalogue *Biochemicals for Research and Diagnostic Reagents*.

Figure 11: *L-Isoleucinal* (2008-2011), Damien Hirst

Gordon Burn, a friend of Hirst, wrote that Hirst,

> "…a longtime admirer of Richter's, believes the 'skin' of the pictures is what makes them identifiably 'Richters'; that his work has always and only ever been about what Richter himself has called 'the smooth, equalising surface'. 'The subject matter is secondary,' Hirst says. 'The unifying thing is the surface. The real care has gone into the surface of every painting. Photographs don't have a surface. It's what makes them different from paintings. It's what painting has left. It's like Richter takes a rippling, moving, delicate surface and hangs the image on top of it. It could have been rolled on in one sheet. They're like sweets or chocolate. They melt.'" (Burn 2008)

In commentary on Hirst's *Controlled Substance Key Painting* (1994) by the Tate Museum, the relationship between Richter and Hirst is explained as follows:

> "Although they superficially relate to them, Hirst's spot paintings differ significantly from the colour chart paintings made by German artist Gerhard Richter (born 1932) during the 1960s and 1970s. Inspired by industrial painters' colour charts, Richter's paintings began as a way to generate paintings randomly, allowing first chance and later mathematical systems, to select colour and determine the order of its placement on the canvas. Richter's goal was to challenge abstract colour theorists such as Wassily Kandinsky (1866–1944) and Joseph Albers (1888–1976) and became purely conceptual. By contrast, the simple but rigid structure of Hirst's spot paintings allows him to avoid the appearance of expressiveness while retaining its process." (Tate 2015)

Hirst relates strongly to Richter's use of color in his color chart paintings:

> "I was always a colourist ... I just move colour around on its own. So that's what the spot paintings came from – to create that structure to do those colours, and do nothing. I suddenly got what I wanted. It was just a way of pinning down the joy of colour ... Mathematically, with the spot paintings, I probably discovered the most fundamentally important thing in any kind of art. Which is the harmony of where colour can exist on its own, interacting with other colours in a perfect format, whatever you do with the colour ... they don't go wrong ... The spot paintings are ... just like, a very exciting discovery, where you get this scientific formula that you add to this sort of mess." (Hirst and Burn, 119–120,126.)

Hirst's discovery, therefore, was that although there was much color theory that had been developed by theorists such as Josef Albers (1963), any set of colors provided a pleasing harmony in the form of his spot paintings. Richter aimed to remove expressiveness from his color chart paintings but found, "I can't see it as a situation where composition and relationships have disappeared. When I place one colour-form next to another, then it automatically relates to that other." (Richter 2009, 179) Whereas Richter found expressiveness and perhaps meaning ("It all starts out easy and unspecific, but gradually a context starts to take shape, and this has a coherence that is the utter opposite of randomness." (Richter 2009, 179)), Hirst found a mathematical purity of abstraction in color.

My color display platform has the potential to move in either of these directions, or perhaps inhabit the space in between, depending on the specific piece displayed. The mathematical abstraction is offered up through the *Random Richters* piece while more expressive connotations may arise in pieces like *Pink Perceptions*.

While Burn writes about Richter's surfaces as making his pieces paintings rather than photographs, the color display pieces present a slightly more complex situation. The surface of the color display is ostensibly flat, as in a photograph, but in reality, it has a slight texture to it due to the physical construction of the piece, somewhat comparable to the texture of paintings versus photographs. And yet, it does not go so far as to achieve a third dimension in any real sense. The color display is also more akin to painting than sculpting, as Burnham describes the dichotomy that evolved in Light Art (Burnham 1967, 287).

As the color display is dynamic and able to show different pieces, it exists somewhere in the realm defined by Richter's charts painted without "apprehending" any kind of image and Hirst's exploration of pure color but takes the process a step further by delivering light direct to the eye rather than relying on the properties of reflected light from paint, while retaining a similar 2D form that invites comparison.

Jason Salavon's color averaging

Jason Salavon (b. 1970) is an American artist known for his digital manipulation of pre-existing media and data to create fine art pieces, which are often impressionistic

composites that reveal properties of the original media or data. He commonly uses two techniques: the photo-collage, in which he typically displays many stills side-by-side, or the photo-average, in which he averages the colors of a large number of images or video stills.

Salavon's work is influenced by Richter, as noted in an essay by Hill (2004, 12) in an exhibition catalog. One piece in particular is clearly derived from Richter's color charts, as can be seen from its name: *374 Farben* (2007) (Figure 12). It is one of a set of three pieces using the color and design of the IKEA catalogue as a foundation. *374 Farben* is a light box covered in a translucent print, with each of 374 boxes representing the average color of the corresponding page of the IKEA catalogue. The boxes are arrayed as in a Richter color chart.

In this piece, Salavon explores various ideas but the one of relevance here is the color study. Although not random by any means, *374 Farben* is quite reminiscent of Richter's color charts in style although the tones are somewhat more muted, pastel, and earthy, while still displaying a wide range of colors.

Interestingly, Salavon's piece employs transmitted light rather than reflected light, as in Richter's and Hirst's paintings. However, even though the light is transmitted, and might seem to be "direct to viewer", there is still a significant difference in the quality of light and possible range of colors displayable with this technique. Salavon's lightbox appears to use fluorescent illumination, which provides a wide range of wavelengths. From that

wide range, each color on the print filters out light leaving behind only the desired color. This is in opposition to my LED color display, in which light is generated only at the discrete desired wavelengths for additive color mixing rather than broadband production of color that is then subtractively filtered, as for a painting. So although Salavon's piece might appear to be a light art piece, it is more like a print in terms of the quality of colors reproducible with the technique. Therefore, my color display still explores new ground beyond other extensions or elaborations of Richter's work, especially in terms of pieces like *Unprintable Colors*.

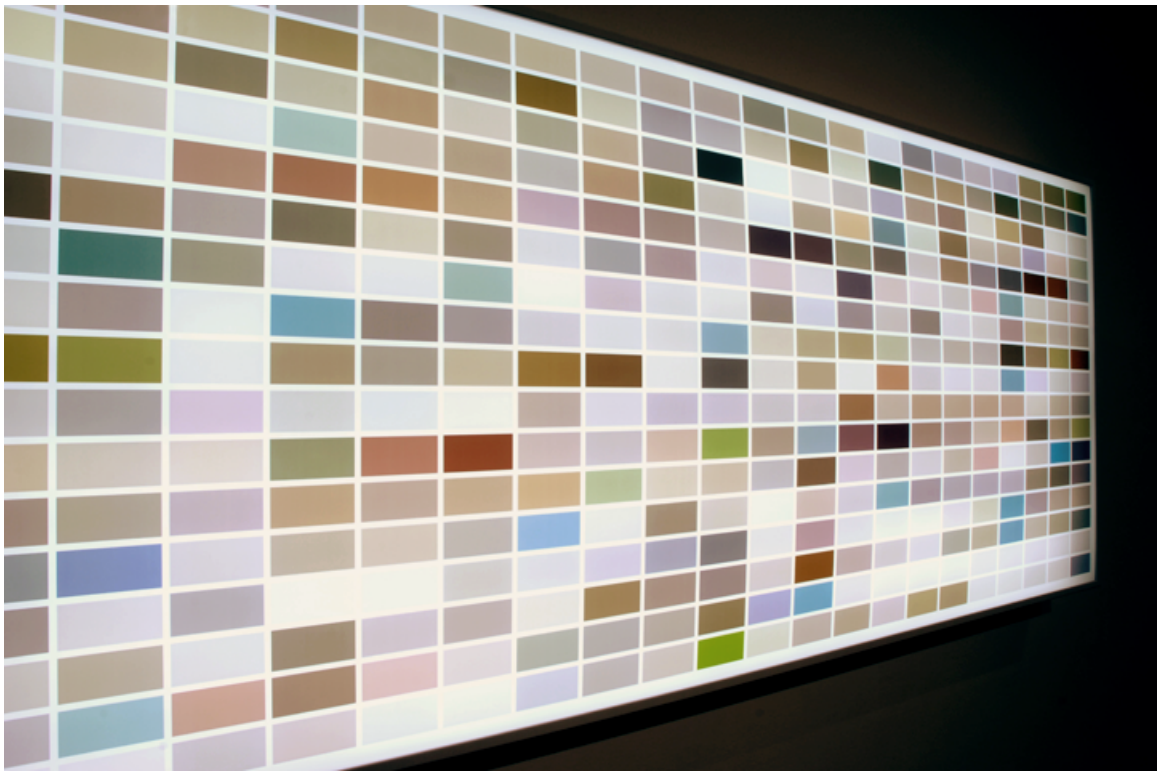


Figure 12: ***374 Farben*** **(2007), Jason Salavon**

Jim Campbell's LED work

Any current artwork made predominantly with LEDs invites comparison with the work of Jim Campbell (Campbell 2010). Campbell is a contemporary San Francisco-based artist working predominantly with LEDs in an exploration of low-resolution film (Figure 13).

Although my work is also LED-based, I feel it significantly different to Campbell's for a few specific reasons. First, Campbell is mostly interested in presentation of film and the limits of visibility when resolution is reduced. He also works predominantly in monochrome, typically in red or white LED light. The overall aesthetic of his work is consistent with most light-work with very clean, modern looking metal, wire, and acrylic as a diffuser.

This contrasts with my work, which explicitly rejects imagery and film and engages directly with the full range of color possible in LED light. I also eschew the industrial look of his work.

However, Campbell's work was inspiring in that it showed various method of displaying LED installations that showed or avoided showing the electronics as part of the work. I chose to avoid showing the electronics involved in the display, as they are irrelevant to the explorations of color that I pursue.

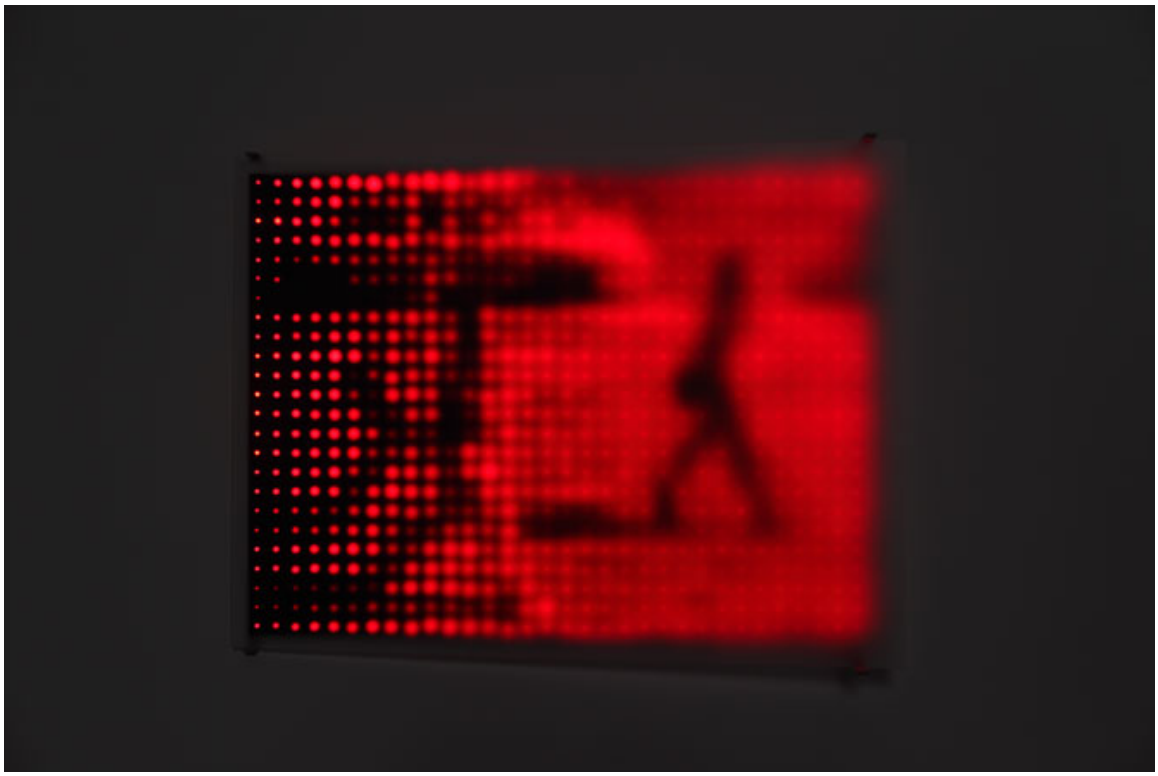


Figure 13: ***Church on Fifth Avenue*** **(2001), Jim Campbell**

John F. Simon, Jr.'s icons

In a seminal 1997 piece of digital art, John F. Simon, Jr. set out to create every possible 32x32 pixel black and white icon in a java program running in a web browser (Figure 14). *Every Icon* is, in effect, a digital counter that explores the connection between numbers and images. Reminiscent of Borges' short story *The Library of Babel*, in which every possible text of a certain length is represented in a vast library, without regard to meaning, *Every Icon* shows every possible icon allowed in black and white in that size without regard to utility.

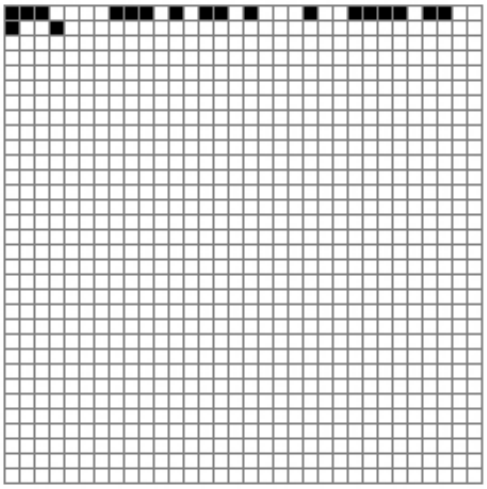
In his artist statement about *Every Icon*, published in *Parachute* magazine and reproduced at www.numeral.com, Simon asks, "What does it mean that one may discover visual imagery so detached from 'nature'?" Simon makes us realize that image making is possible separate from image recording, and the color display is an ideal platform for continuing those kinds of explorations.

The RGB colors presentable by the color display although, by definition, occurring in nature, are quite different from the actual colors observed in any natural setting as the production mechanism for photons of light by the light-emitting diodes (LEDs) of the display is not to be found in nature. With direct reference to Simon's work, *Every RGB Icon* is a piece for the color display that shows not only all black and white icons but all color icons that have what is called 24-bit color depth, or 256 levels of each of red, green, and blue in their color compositions. If the color display were made to the same resolution as Simon's piece (32x32) then *Every RGB Icon* would take approximately

10^{7400} years to complete. Even at the reduced size of 16x16 pixels, it would still take 10^{1850} years to complete. Interestingly, that is such a large number that the rounding error in it is considerably greater than the lifetime of the universe so far (~10^7 years).

The color display further deconstructs the possibility of an image to its parts as a set of colors, and shows that the appearance of meaningful images is, in fact, a very small subset of what can be shown as a color presentation of a given size.

Given:
An icon described by a 32 X 32 grid.
Allowed:
Any element of the grid to be colored black or white.
Shown:
Every icon.



Owner: computer fine arts
Edition Number: 92
Starting Time: May 30, 2001, 3:06:07 pm

(c)1997 John F. Simon, Jr. - www.numeral.com

Figure 14: ***Every Icon*** **screenshot (1997), John F. Simon, Jr.**

4. Cultural and political context

All art is created of a particular time and place, and influenced by the surrounding cultural and political environment, even if it is not explicitly considered in the making of the work of art. This section explores my own personal engagement with the cultural/political environment in which I am currently making art and how that environment influences my interest in the specific platform and pieces discussed in this paper.

In, but not of, Silicon Valley

The color display is a platform born of a techno-scientific age and culture. Having been based in Silicon Valley for the past decade, but not employed by the tech sector, has led me to an insider/outsider perspective on innovation, development, and entrepreneurialism. In particular, recent apparent changes in the cultural landscape of Silicon Valley weigh heavily on my mind.

The origins and growth of Silicon Valley in the 1960s coincided with the origins of the Northern California counter-culture, based in San Francisco. They came together in a kind of techno-utopianism that was extremely influential on broader culture over the decades that followed. Choosing a strong exemplar, Charlie Gere writes, “Apple was also felt to be a particularly Californian success, mixing entrepreneurial capitalism and counter-culture ethics without the sense of contradiction that such a combination might

evoke." (Gere, 2008)

It is precisely this contradiction that provided a lot of the energy of technological development in Silicon Valley since the 1960s as these opposing forces or capitalism versus counter-culture found common ground. Gere, again, puts it well:

> It might seem at first that, both in theory and practice, neo-liberalism would be at odds with counter-cultural thinking. But in fact, as remarked before, there is a remarkable degree of consensus. Both neo-liberalism and the counter-culture elevated the individual over the collective. Both also proclaimed the necessity of freeing the individual's capacity to act from the tyranny of organizations and bureaucracies. The hedonism that was a characteristic part of the counter-culture is not so far from the neo-liberal appeal to the self-interest of the consumer. In a curious way, the pursuit of neo-liberal policies is also the triumph of counter-cultural ideas.

Despite being written in 2008, a lifetime in the world of Silicon Valley, this analysis remains relevant, most likely due to the growing bubble of tech investing, akin to what was happening in 2008. However, now, the counter-cultural forces inherent in the birth of Silicon Valley are largely being dominated by capitalist tendencies. Living in the Valley exposes one to an almost palpable gold-rush-style adventurism among the younger, white, male privileged workers drawn to the promise of a windfall return on an idea that is claimed to be revolutionary but is, in most cases, merely incremental. The amount of money being poured into what amount to lifestyle apps that serve the already privileged

verges on obscene.

Despite this evolutionary drift of the cultural scene away from counter-cultural principles into the pursuit of mainstream cultural adoption of new technologies, the proponents of these technologies cling to the counter-cultural talk of change, innovation, and creativity.

This collective use of sophistic language is perhaps most strongly captured in the writing of Richard Florida and his concept of the "creative class." (Florida 2012) As other commentators have noted, his use of the "creative class" no longer refers to the group of writers and artists that the terminology might imply, but instead correlates most strongly with a highly-educated privileged class of people who typically work in jobs that rely on the processing of information. And yet, it appears that the Silicon Valley startup worker subgroup wholeheartedly buys into the notion that what they do is truly creative and potentially world changing.

Paul Feyerabend writes,

> The conceited view that some human beings, having the divine gift of creativity, can rebuild creation to fit their fantasies without consulting nature and without asking the rest of us, has not only led to tremendous social, ecological, and personal problems, it also has very doubtful credentials, scientifically speaking. We should reexamine it, making full use of the less belligerent forms of life it displaced. (Feyerabend 1987)

This “conceited view” is all too prevalent among startup founders and workers in Silicon Valley and has potentially only worsened with the culture now celebrating “unicorn” companies (valued at more than US$1 billion) and their founders as exemplars of success and the heights of aspiration.

Despite the overt emphasis on innovation and libertarian culture, most of the development of products in Silicon Valley remains quite conservative in approach, having dogmatized many of the past successful processes of the Valley.

Performing creative acts within Silicon Valley is a process that involves playing by the unwritten cultural rules but trying to find the boundary or edge cases of those rules, where creativity can walk the fine line of being acceptable to the dominant Valley culture as enforced by the group of venture capitalists that influences where vast sums of money flow.

This line exists not only in behavior but in aesthetics and process as well. For example, aesthetic choices made in Silicon Valley are dominated in hardware by Apple, Inc. and in web design by a particular mode of white-space-dominated clean-appearing long-scrolling icon-based design. Hence the use of paper, cardboard, and wood as the main materials of the color display. It is a rejection of the dominant aesthetic while still playing close enough to the “rules” that it isn’t rejected outright by the establishment. In fact, various viewers of the piece were unable to tell the color display didn’t have a black-painted metal façade like they expected from first viewing at a distance. The color

display has also been successful in the views of establishment Silicon Valley with interest from major companies and Stanford University in either purchasing or showing the piece. I find perverse pleasure in thinking that this subtle counter-Silicon-Valley statement could potentially end up in the heart of Silicon Valley on display.

Growing defiance of the dominant paradigm of work in the Valley has manifested itself as the Maker movement, a loosely tied, sprawling web of tinkerers with an interest in do-it-yourself techniques and tools, arising in the past decade. Ironically, the direction of the Maker movement, which is predominantly a techno-social movement, is entirely consistent with Silicon Valley's ethos and increasingly reflects its culture and identity, as explicated by Leah Buechley (2014) in her telling analysis of the lack of diversity among members of the Maker community.

One key tenet of the Maker movement is an alignment with the open source movement. This is an interesting contrast between the values claimed by many tech companies and their behaviors, which remain close sourced in most cases, due to the immense intellectual property value of their software and hardware engineering. And yet, a skeptical view of the Maker movement will quickly reveal some deep problems in the relationship between open-source culture and labor and diversity, most particularly arising from asking "Who benefits from the 'free' labor contributed by all these open-source makers?" It also avoids the question of privilege and who is able to contribute this labor unpaid. Following the thread of this question quickly leads back to the modus operandi of many Silicon Valley startups, of exploiting "crowdsourced" "content" for the

benefit of the company from a mostly monolithic group of contributors.

The color display plays with the tensions between artistic expression and creativity versus the current Silicon Valley culture. It exploits the developments of engineers and artists in technical terms but applies that knowledge in a search for edge cases that break beyond the typical application of these technologies.

One common response to the piece has been that it could be used to show images or video. While that is unequivocally true, I have chosen to not use the display for this most obvious of applications. Showing imagery/video would be consistent with using the platform in the way it urges, given the context of screen development in Silicon Valley. However, using it only for color explorations pushes the technology in a potentially unexpected direction, and certainly runs counter to the forces of utility.

The boundaries of science

The color display's form and actions complement each other in a similar way to how the paradigms of science complement the constant attempts to break beyond those paradigms. Progress in science typically occurs when boundary cases are explored to the breaking points of the dominant paradigm, at which point "paradigm shifts" sometimes occur, to use philosopher of science Thomas Kuhn's framework of the development of science as evolutionary progress punctuated by revolutionary changes (Kuhn 1962).

The platform of the color display is rigidly formalist in structure and approach. It

employs a strict geometric architecture consistent with its prior influences. The possibilities for the color display cover all enumerable territory in RGB color space but are confined to none in particular. Just as the laws of science allow for a large defined space of possibilities, the interesting behaviors are confined to small subspaces, often at the boundaries of possible. The particular subspaces usually explored are defined by the prevalent culture and the properties of the display itself.

The pieces shown on the color display are more playful edge cases of what can be achieved with color. The platform is predominantly conformist in that it does indeed urge exploration of the imagery/video subspace, while the pieces are non-conforming explorations of boundaries.

Conformism or not

The tension between conformism and non-conformism and the mirroring of a scientific structure, in the sense of finding the new in a rule-bound system, are directly formed by my personal history and experience. Playing by the rules has always appealed to me, but primarily in the sense of discovering what the rules will allow as unusual cases of behavior. Rules and constraints can provide creative impetus, especially when their limits are stretched, as has been masterfully shown in literature by the *Ouvroir de literature potentielle* (OuLiPo). Science also affords a playful approach to understanding the world around us. That play is constrained by empirical evidence but science tends to progress when the limits of the rules are discovered in the form of unexpected behaviors or phenomena.

In addition, all science is necessarily contingent, with theories being revised and improved precisely when edge cases show the dominant paradigm is lacking in some aspect. So there is an individual reward for non-conformism, in that the boundaries of science can be expanded, while the institutional environment rewards conformism, as is normal for all large institutions. This tension is highly present in science, in its practice, process, and administration.

The creation of meaning

We are all familiar with the kind of pixelated electronic display of which the color display is one simple instantiation. And yet, those kinds of displays are usually used semantically in a limited number of ways. They tend to be 1) displaying textual glyphs, 2) displaying iconography or pictograms, or 3) showing recorded video or created animations. The goals of the pieces shown on the color display try to break beyond these categories.

In particular, the color display pieces aim to create meaning and commentary through emotive prompts (the use of color in e.g. *Pink Perceptions*), the emergent meaning in randomness (e.g. *Random Richters*), or enumeration to the point of meaninglessness (e.g. *Every RGB Icon*). In the most basic sense, the color display operates in a different way merely by working in the space of colors rather than text/image-based information, despite the latter being reducible to the former.

5. Audience reception

Edges of Color was displayed in the Digital Arts Research Center at the University of California, Santa Cruz from April 28-May 1, 2016 as part of the MFA show *Blindspot*. Half of a white-walled room, divided by a white curtain was dedicated to the piece, with the display wall-mounted vertically centered in a 10' division of the room (i.e. with about 1' clearance above and below) and horizontally centered in a 14' width. A couch sat about 20' back from the piece for people to sit and contemplate the display. A small table with a set of information cards that keyed each piece shown to explanatory text was next to the couch.

The white walls in a darkened room was a very effective display space as the color reflected from the screen illuminated the floor and walls helping add to the experience of being immersed in color, especially for *Pink Perceptions* (Figure 15).

The information cards were popular with a few hundred being taken during the show. Some people took one card, with the *Random Richters* card most popular, while others took one of each, commenting that they would mount them on their wall.

A few hundred people came through the show and I was in attendance for the majority of the 25 hours the exhibition was open to the public. People generally took the couch as an invitation to sit and it was occupied much of the time that people were present in the room. Viewers typically sat for at least 5 minutes (enough time to see three of the five pieces shown on the display) with some staying as long as 40 minutes. Very few visitors

came by and left within a minute. A sizable and greater-than-expected proportion of viewers stayed for a full 10-minute cycle of the display. A number of visitors returned multiple times to contemplate the display.

The most common reaction from viewers was a joyful surprise at the intensity of colors. Other common reactions were intellectual curiosity, evidenced by the asking of questions; awe; and laughter. Many viewers commented that they would like to have the piece on their wall at home.

Intriguingly, there did not appear to be a standout favorite piece of the five shown. Indeed, each piece was remarked as a favorite by a fraction of viewers. I had expected that *Every RGB Icon* might be considerably less popular than the others but it had a large share of fans in the audience, who engaged with the piece on an intellectual and mathematical level. Conversations on randomness and quantum physics were common after seeing *Random Richters*. *Pink Perceptions* generated occasional discussion among viewers in which they all determined when the color pink came or went for them, showing that it was indeed different for different viewers. *Colour Lovers* was the most aesthetically pleasing for many viewers, while others found amusing the fact that there was indeed a website dedicated to the topic, with some viewers indicating they would be looking it up after the show. *Unprintable Colors* generated the most surprise, as most viewers were not familiar with the concept of color gamuts and the fact that different methods of color representation allow for different ranges of colors to be shown.

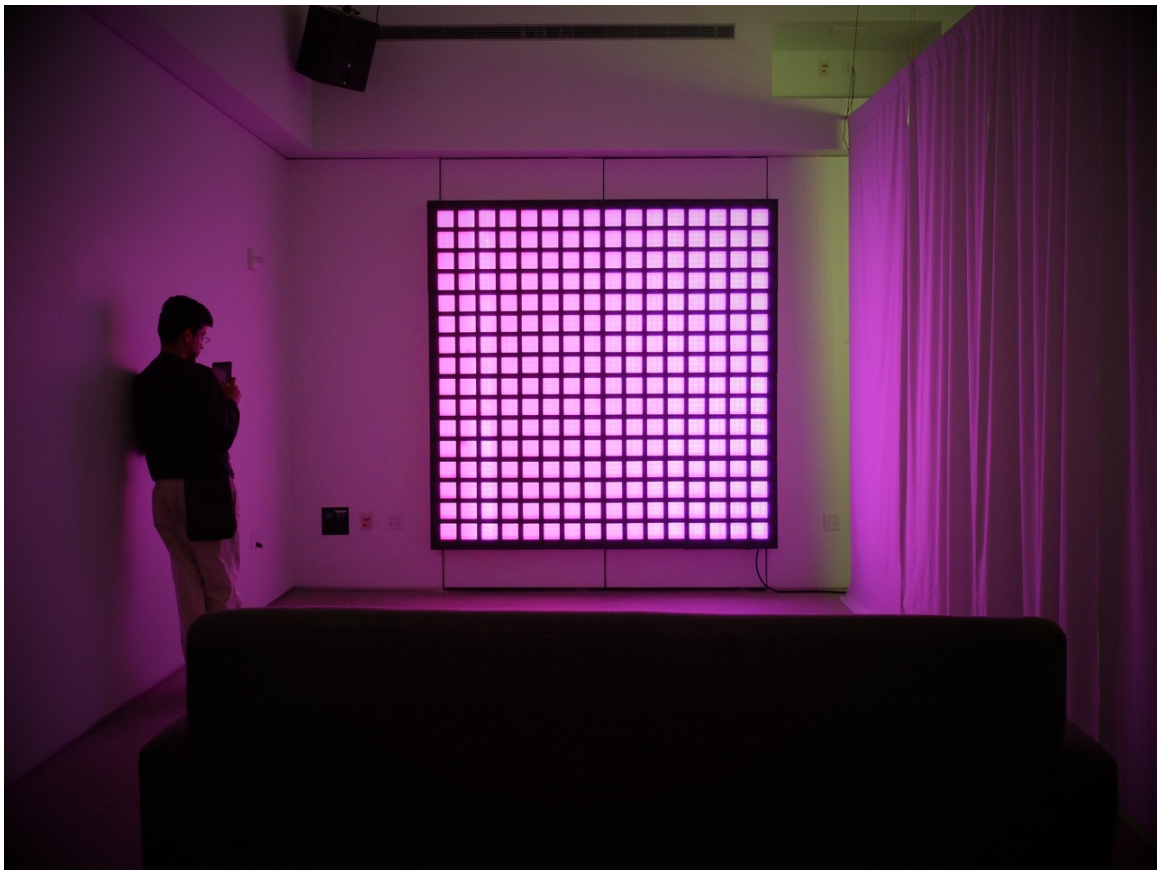


Figure 15: ***Pink Perceptions*** **on display at the University of California, Santa Cruz.**

6. Conclusion

The color display and pieces shown thereon are an attempt to reconcile more than a decade of living in Silicon Valley while currently engaged in the creative endeavor of artmaking. Specifically, the tension between formal, constrained, and rule-based systems and creative work is interrogated in terms of the possibilities lying at the boundaries of what is possible in those systems.

The color display investigates these topics through the realm of color light presentation, which enters into conversation with a long and distinguished lineage of color art. It does this partly by direct reference to the color swatch imagery of Gerhard Richter as a primary reference, with additional reference to many other artists who have worked in abstract formal color presentation. This reference manifests in the architecture of the color display itself, appearing as a set of color swatches in an orderly grid, but transposed to additive color light emission, rather than subtractive color light reflection, as occurs in painting. The similarities with the color swatch works are perhaps most directly referenced in the pieces *Colour Lovers* and *Random Richters*.

Although color light has been used extensively for artistic application, few of those works deliberately study the differences between color light and color paint, as is done in the piece *Unprintable Colors*. Additionally, *Pink Perceptions* directly addresses the physiology of sight and how color works scientifically, but presenting it a way designed to invoke subconscious emotional response, just as the eyes react to light subconsciously.

Finally, *Every RGB Icon* shows the abstraction of color combinations to the point of meaninglessness, as the presentation of every possibility precludes the specialness of any particular possibility. And yet, the piece turns on itself by requiring longer than the age of the universe to run, thereby stating that we must make some particular choices, but it is up to us to make meaning from those choices, or not.

The color display allows for an almost unlimited amount of exploration of colored light in many different contexts, only a small amount of which has been investigated so far, and is still only a small fraction of the potential color space accessible to humans. In a world in which color on digital devices is omnipresent and yet extremely limited, it is important to continue to determine what else can be done with color, being one of the most powerful semantic messengers we have available to us.

For example, not only are web-safe colors limited to 216 choices, but the overall combinations of colors and aesthetics of the world-wide web at the present time are extremely limited, with designers opting for choices that appeared to have been inspired by the Swiss International and Bauhaus styles. (Kane 2014, 197) Conventional business-oriented web design, like most graphic design, moves in waves of trends and the current wave does little to explore the potentialities of color space.

It is also important to note that the color display nowhere near exhausts the potential color spectrum visible to human eyes. Specifically, it depends on red, green, and blue LEDs that each emit light at specific narrowband frequencies, chosen to be near the peak

sensitivity of the wideband color receptors in the retina. The possible colors observable are varied but we sometimes see other colors when light of frequencies very different to the R, G, and B central frequencies are present, such as produced by fluorescent emitters that range from Day-Glo color to green fluorescent protein, used in many biochemistry experiments as a genetic signal flag, but also famously in Eduardo Kac's *GFP Bunny*.

Fluorescent colors are further used in everyday life in products such as washing detergents that make colors glow brighter than they would by simply reflecting light. Curiously, the particular colors that the detergents fluoresce in depend on the cultural and environmental context, with hot climates having detergents that fluoresce toward the blue end of the spectrum whereas cold climates employ red-end fluorescence. These principles are applicable to both emitted light and reflected light so custom colors can go far beyond what is possible in RGB illumination or CMYK printing.

Although some of these fluorescent colors are not accessible in the color display discussed here, there is still plenty of color space still to explore using only RGB colors.

The color display exists as a platform for further exploration of color studies, light art, or put to any application not considered in this paper, of which there are too many to count. It is a simple work, in the sense that it is just a grid of 256 colored lights, but still allows for nuanced exploration of the boundary cases that help us define and understand the limits of not only color, but science, technology and culture.

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