Supplementing Fine Art Education with Digital Interactivity

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Digital artefact - www.artmovement.dominicfee.info.

Abstract

This dissertation documents the development of a project which I undertook to create a web-based educational resource, with interactive elements, designed to assist in the education and appreciation of fine art, specifically abstract painting. The website contains textual information, static imagery and a number of coded simulations of well known painters' works with which visitors can interact. The methodology of researching and writing the code for the interactive artefacts based upon the paintings, using the Java-based programming language Processing is outlined. The process of the overall website design is explained and an overview of the educational concepts introduced throughout is given, with particular reference to how the various elements contribute to their delivery.

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Declaration

Supplementing Fine Art Education with Digital Interactivity

This thesis is presented in partial fulfilment of the requirements for the M.A. in Digital Arts and Humanities, University College, Cork. It is entirely my own work and has not been submitted to any other university, or for any other academic award in this university.

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Dominic Fee

31st August 2016

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<u>Introduction</u>

As a visual artist who has engaged in a busy art practice for some years, encompassing a selection of varying techniques, I am regularly on the lookout for new working methods which may give a fresh dimension to my work. Also, having had a significant involvement in art education over the same period, from primary to third level, the search for relevant and appropriate teaching methodologies and resources is equally important. Coupled with this I have always had a very keen interest in abstract art, an admittedly broad term but simply put, art in which there is no attempt to depict places, people or things or mimic the natural world in any way. Even though many artworks and artists who exemplify this style date from the very early years of the twentieth century, and have become commonplace in contemporary culture, I regularly encounter anecdotal evidence from people who feel somewhat alienated and confused by it, perhaps struggling to see the cultural merit in what is often, in essence, a collection of lines, shapes and colours. This is a point of view to which I can relate all too well, as before I received a formal education in art theory and history I would have felt exactly the same way. I have also heard many colleagues remark on the relative difficulty of teaching the principles and appreciation of abstract art to students.

Having almost embarked on a career in engineering, completing a certificate in electronic engineering in 1990, I have retained a particular interest in the intersection of art with other fields, particularly science and engineering. The electronics course contained a computer programming module in BASIC programming (Beginner's All-Purpose Symbolic Instruction Code) a language which though now long obsolete gave me an interest in coding which has remained since. About two years ago, while searching for a language with which to update my coding experience, I began to use Processing, an open source programming language built on the Java language, particularly suited to the generation of interactive graphics. Though struggling with it initially, the archaic syntax and structures of BASIC still informing my approach, before long I began to achieve some competence in its use. To set myself some exercises with which to build on my skills, I wondered if it might be possible to author some code which could generate an abstract artwork, and allow for some level of interaction with it. This led to my first interactive program, a version of Piet Mondrian's famous painting "Composition with Lines" (1917) with which I was able to draw the work's characteristic black bars on the screen with the mouse. Though hardly sophisticated, it used a degree of randomness in the placing the drawn elements and formed a starting point on which to build. Fascinatingly, I subsequently realised that American computer scientist A. Michael Noll had used a computer to generate a coded version of the same painting in 1964, a full fifty years before my attempt (Miller, 2014, p. 71).

In deciding on a research project and related digital artefact for this MA program, I wanted to develop something which would somehow bring together all of the above interests and also provide scope for further development in the future. As I had subsequently worked on further interactive programs dealing with other abstract artists, I decided the best use of these individual pieces of code would be to gather them all together on a custom-built website to make them available for public use. To give the site an overall purpose, I decided it should be an educational resource, comprising imagery and textual information as well as the interactive Processing programs. Students of visual art or indeed anybody with an interest in art generally would be able to navigate through the site page by page, encountering different styles of artworks and being introduced to a number of key theoretical concepts, the hands-on interactions hopefully enhancing an understanding of the written content. This dissertation traces the research process and methodologies involved in the development of this resource, which is available at www.artmovement.dominicfee.info.

<u>Literary Review</u>

In the early 1960s Billy Kluver, an electrical engineer working for Bell Telephone Laboratories in New Jersey, became the catalyst for a rich period of collaboration between artists and engineers which would lead to the formation of the organisation "Experiments in Art and Technology" (E.A.T.). In his book "Colliding Worlds, How Cutting-Edge Science is Redefining Contemporary Art", Arthur I. Miller chronicles the crucial role played by Kluver and Bell laboratories during this period of cutting-edge experimentation, which would soon lead to the production of the very first works of computer-generated art. Kluver, born in 1927 in Monaco, began working in Bell Laboratories in 1958. His aim was to remove the boundary between the arts and science, with Bell Laboratories agreeing to fund his research in this area. One of his first projects was to work with Swiss Dada artist Jean Tinguely on his piece "Homage to New York" a contraption made of a collection of small machines which was designed to completely destroy itself during its first, and only, exhibition. Tinguely contributed the anarchic critique of society's materialism and obsession with possessions, while Kluver supplied the engineering expertise to construct the body of the machine, including a timer mechanism to synchronise the "glorious act of mechanical suicide." (2014, p.37) He also owned the car in which the pair drove around the local area to scavenge for the machine's parts. Tinguely's piece, along with another Kluver collaboration with the artist Robert Rauschenberg, were eventually exhibited to a select invited audience in a performance which was somewhat spoiled by technical failures, resulting in the local fire department having to be called to extinguish the flames.

Though somewhat catastrophic, there was however sufficient interest in the project to lead to further events, notably "9 Evenings:Theatre and Engineering", the brainchild of Kluver and Rauschenberg and the first major event to feature collaborations between artists working with scientists and engineers. It was after the substantial interest generated by this event that Kluver founded Experiments in Art and Technology to formally develop further cross-disciplinary collaborative projects. Interestingly, at a press conference held to formally launch E.A.T. to the public in 1967, an exhibition of works was held which featured one of the first examples of a computer-generated artwork. "Studies in Perception 1" had been produced by two of Kluver's colleagues from Bell Laboratories, Ken Knowlton and Leon Harmon. This piece was a result of the artists' experiments with scanning photos with a television camera and converting the resulting tones to electronic symbols. The picture had caused something of an internal scandal originally at Bell Labs, as it depicted a female nude (though only just discernible as such). Now however, having been shown at the E.A.T. event, and subsequently published in the New York Times, the company's public relations department openly endorsed the work and encouraged its creators to highlight their roll in its fabrication (2014 P.50).

Bell laboratories was also notable for having employed computer engineer A. Michael Noll who, even before the creation of "Studies in Perception 1" had been experimenting with the laboratory's early computers to investigate their potential for the creation of graphical imagery. A 1962 technical memorandum on the production of computer-produced patterns provides a fascinating insight into Noll's methodology and the type of technical resources available to him at that time. Using an IBM 7090 computer and a Stromberg-Carlson 4020 Microfilm Printer, Noll wrote subroutines to plot a series of points generated from previously specified numerical arrays. Another subroutine was written to join selected pairs of these points together to form sequences of lines. Although the limitations of the available resources restricted the images to compositions made from straight lines only, I find many of the printouts to be surprisingly complex and sophisticated. Tellingly, the prevailing attitude of the art establishment towards such experimentation may be summed up by the following reflection: "Rather than risk an unintentional debate at this time on whether the computer-produced designs are truly art or not, the results of the machine's endeavours will simply be called 'Patterns'" (Noll, 1962).

In more recent years, digital tools designed to generate original imagery or manipulate existing images have become increasingly more sophisticated, user-friendly and commonplace. As a result of the increasing usage of ICT resources in educational institutions, their potential benefits specifically to art and design education have become the subject of much attention. In her 2004 paper, 'Open Minds and a Sense of Adventure: How Teachers of Art & Design Approach Technology', Joyce Wood examines the findings of two UK based studies which investigated the use made by teachers in twelve different subject areas of ICT tools with their student groups. Particular attention was paid to the ways in which such tools facilitated the teaching of the central concepts of their subjects, and whether there were educational benefits to be gained from their usage which were not available from other methods. Out of all the teachers surveyed, it was found that teachers of art and design were particularly likely to embrace the use of ICT tools and also to be the most inventive with their usage. This was despite there being issues with the relative expense of and access to ICT equipment and software packages, and a dissatisfaction with the level of training provided in their usage. Indeed the very resourcefulness which is required of art teachers to compensate for their typically meagre materials budgets is suggested as a contributing factor to their capacity to embrace ICT (p.180).

Certain advantages were found in the use of software-based tools over traditional techniques. For example, while working with scanned or photographic imagery in a graphical manipulation program such as Photoshop, it was found that because they could undo their actions, students often had a less

inhibited approach to experimentation which led to a more creative end result. It was also found that access to such tools had the effect of encouraging those students displaying less ability with the traditional skills of drawing and painting, allowing them to work through visual ideas with more confidence. Also, a good level of experience gained in the use of such technology and software was found to particularly benefit those students who would go on to pursue careers as visual artists and designers, given the increasing usage and prominence of such tools in these fields.

The intersection between art and design education and the art profession itself is examined in more detail by Avril Loveless in her 2003 paper 'Making a Difference? An Evaluation of Professional Knowledge and Pedagogy in Art and ICT.' Loveless examines the 1999 secondary school project 'Art on the Net' which explored the intersection between practising artists, students and art teachers using digital technologies in schools. A video artist, a sculptor, a performance artist and a photographer worked in collaboration with art teachers and their students to produce projects in four schools in England at GCSE and A level. The paper examines how artists, teachers and students incorporate ICT tools into their practice and subject knowledge to develop appropriate ICT concepts and skills, and examines the particular challenges raised by the use of such pedagogical tools in the school environment. Difficulties arose with the level and nature of the access granted to the schools' ICT suites, the art departments' projects tending to be allocated a lower priority than the schools' non-art related ICT lessons.

However, the process was considered to have benefits for all concerned. By manipulated images digitally in various ways, the students were given the opportunity to consider concepts such as copyright, authorship and collaboration. The ability to share their work with communication technologies afforded them the opportunity to think about their work in terms of an audience, and discussions were generated focusing on the difference between making original work with digital tools and simply appropriating images from the internet (Loveless, A. 2003, p.151).

In more recent years, since the advent of Web 2.0 and an increasing availability of open source tools, the landscape has changed considerably in terms of the feasibility and accessibility of producing digital resources. The possibility of authoring one's own resources now exists to a far greater extent than ever before, resulting in a far greater number of free web-based resources being available for art students and teachers. For her 2016 paper 'The Landscape of Websites for Art Education and a Portrait of their Designers', Tingting Windy Wang sourced over 70 art teaching and learning websites, had many of them evaluated and interviewed four of their authors to explore their motivations and intentions. Having completed the evaluation process, Wang presents and discusses the twelve top-

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rated websites. Many of the sites contain collections of lesson plans for various ages, online courses for art educators and libraries of visual art images, texts and other resources. Resources providing the facility to share one's artworks to online communities, such as Deviantart, were also popular. One website, Artsology (www.artsology.com) even provides some Flash-based gaming activities with art-historical themes.

However, despite the relative richness and diversity of content, the survey found that most of the websites considered were static in nature and failed to incorporate emerging technologies to provide interactivity, denying learners the chance to practice their skills or assess their learning results (p.201). It would therefore appear that there is currently a pressing need to develop web-based resources dedicated to art education with an emphasis on greater levels of student interaction.

Research Trajectory – Physical to Digital

My interest in the pedagogical aspects of this project, particularly in the area of allowing others to have a role in the authorship of existing artworks, has its roots in several earlier, non-digital projects undertaken in recent years which relate to my own artistic practice. In 2013, while completing a masters program in fine art in the Cork Institute of Technology, I became interested in questioning the typically non-interactive nature of artworks housed within art galleries and museums. My research goal during this course was to produce an artwork which was not finite and unchanging, but one which over the course of an exhibition could assume different forms and potentially be moved around and be adapted to its environment. Furthermore, I wanted to produce an artwork which could potentially be authored by other people, in order to investigate the nature of choice and decision-making in the artistic creative process.

I eventually designed an artwork comprising a modular system of wooden components which could be assembled together in a set number of different ways and was highly reconfigurable - essentially a tool-set for making artworks rather than a finished piece. Over the course of a two week exhibition period, I would reconfigure the piece at night in order to have a different arrangement on display each day. On one of the days I invited a class of second year interior design students from Saint John's Central College, Cork to come up with their own design for the piece, having previously visited them in their college, demonstrated the workings of the components and explored some design ideas with them. I chose to work with interior design students as I expected they would have a particular interest and facility with conceptualising and constructing three dimensional designs.

On the day they worked with the art piece they formed themselves into small groups and eventually built a Christmas tree (it was December) and a model of a penny-farthing bike. I was fascinated by the fact that they chose to work with the pieces not in an abstract way, as I would have tended to do, but made versions of recognisable, even seasonally topical objects from the world even though, given the limitations of the components used, they were necessarily abstracted.

Figure 1: *DLV* workshop in progress (2013)

Figure 2: *DLV* completed installation (2013)

Interested in the possibility of producing further artworks with the potential for an interactive educational aspect, I designed another modular piece for a gallery exhibition held in the Mermaid Arts Centre, Bray, County Wicklow in 2015. This time, the 1100 individual components were cut out by hand from mounting card and were essentially triangular in shape. They were designed to be assembled together to form pyramidal structures and elongated chains, or arranged on a flat surface to form two dimensional tessellating geometric patterns. Entitled "modUlar", the final exhibition comprised a floor-based arrangement designed by myself, and on a nearby table was a selection of the individual components which were stacked in piles, not having been assembled. A sign was placed on the table inviting members of the public to construct their own forms out of the pieces.

This proved popular with the public on the opening night and throughout the course of the exhibition, particularly among children and younger people.

Figure 3: *modUlar* installation (2015)

Leading on from this exhibition, I was subsequently invited to take part in an art project in the Bandon Grammar School, Cork, to work with a group of transition year students as a visiting artist. The brief was to produce a large scale artwork or series of artworks which could remain on display within the school building, would in some way relate to the subject of mathematics, and would be based on the modular forms from the Wicklow exhibition. Given their interactive potential and concern with geometry, the modular components were considered to be a good fit for the brief. As there were only three days available to work with the students and complete the installation of the artwork, the students' art teacher, John Twomey, and I designed a schedule in which we allocated the first day to the marking and cutting out of the several hundred pieces required from foam-board, which had already been painted in a selection of colours by some of the students. The second day was to be devoted to assembling them into finished art pieces and the third for the final installation of the artworks in the allocated space.

My particular interest in this project lay in observing how the students would use their own initiative and work together to author the pieces of artwork. I gave a brief introductory talk in which I outlined the concept and development of the modular pieces, and demonstrated the various ways in which they could be fitted together. Other than a brief brainstorming session during which some potential ideas were discussed, I left it entirely up to the students to decide what they would choose to make from the pieces, how they would organise themselves into groups to work and whether they would make several individual artworks or all collaborate on a single piece.

At the end of a very labour-intensive first day, over four hundred individual pieces had been cut out by hand. On the second day, out of a group of twelve students, about four groups were loosely

formed which began to work largely independently of each other, each with different structural concepts and approaches to colour. The forms being built were essentially abstract, each group experimenting with various configurations of the components without necessarily attempting to build a sculpture which resembled anything to be found in the natural world or possessing any particular narrative content.

Figure 4: Bandon Grammar School project, work in progress (2016)

At first it appeared that the end result of the project would be a series of distinct, abstract sculptural objects. After a lunch break however, having become more comfortable with the components and gained some confidence in fitting them together, the individual student groups began to come together and have conversations about the possibility of combining their efforts into one or more single pieces. After a period of discussion, some of which was concerned with the television series "Game of Thrones", it was decided by the student group that everybody's efforts for the remaining time would be best concentrated into making a model of a large dragon, a creature which features prominently in the series. As well as being highly relevant in terms of contemporary popular culture, the dragon would be a very apt choice as the designated space was a large glazed atrium area within which the final work would be suspended far overhead, giving the appearance of the dragon flying down from the sky into the school building.

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Once this decision was made, a focus on a more inclusive form of collaboration and a renewed, tangible urgency was evident in the entire group's behaviour. A large pyramid-like structure was designated as the dragon's head, for which horns and teeth were quickly fashioned and added. Two chain-like elongated sections became the neck and spine, and a separate team took on the task of assembling a large pair of wings from the numerous off-cuts left over from the previous day's cutting. Within a couple of hours all the individual body parts were ready, and the final creature, almost five metres in length, was finally installed in the school building.

Figure 5: Bandon Grammar School project, completed installation (2016)

For me, these projects would appear to reinforce the value of modular toys or tools which provide the potential for producing a very wide range of outcomes yet, unlike the almost complete freedom offered by materials such as clay or paint, intersect with each other in a predetermined, and limited number of ways. This encourages the user while building with the components to consider the rule-set inherent within their design, while also conceptualising the actual form they wish to build. If a particular object or cultural artefact is in mind, such as a bicycle or dragon, the resulting familiarity can make the process more meaningful and engaging, and a successful replication that much more satisfying and measurable. I see the Processing sketches in my digital artefact essentially as a digital equivalent of these physical modular components. While in many cases they allow a good degree of freedom to the user and hopefully embody a certain playfulness, their code is written so that they exhibit very specific behaviours while being interacted with, behaviours which are derived from the specific characteristics of the particular artworks they are based on.

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Methodology – Coding Simulations with Processing

This chapter outlines the methodology behind the writing of the coded elements in the project by examining a selection of the artworks featured in the final website. In each case, a brief description of the compositional elements within the relevant artwork is given, the intended nature of the accompanying interaction is outlined and the subsequent coding process described.

The programming language and environment I have used to create the interactive exercises in this project is the open source language Processing, which has its home on the web at www.processing.org. It was developed on top of the Java programming language in 2001 at the Massachusetts Institute of Technology Media Lab, by Casey Reas and Benjamin Fry, who were graduate students at the time. Its premise is to teach the fundamentals of computer programming within a visual context, though it is also considered to be a production tool of a professional standard to be used for prototyping and project production, and exists as an alternative to proprietary tools (Shiffman, 2015, p.xi,). As an open source project, Processing is very well supported through its website and GitHub repository with a very active community providing many tutorials, project examples and forums. It has several sister projects including p5.js, an interpretation based on JavaScript to facilitate greater browser and web compatibility, and Processing for Android which allows its programs to be run on tablets and other devices using the Android operating system.

Once downloaded and run, Processing features its own integrated development environment (I.D.E.) in which its programs, referred to as "sketches" are written and run. Among the features of the I.D.E. are many sketch examples to introduce a full range of coding topics, and the ability to search Processing's online reference library of commands and functions. As a learner coder, I found it quite intuitive and helpful. Though Processing sketches are capable of great complexity, the programming language is characterised by two core functions: *setup* and *draw*. The setup function is run only once when the program is executed, and typically includes information about the canvas size, background colour and other global properties of the sketch. The draw function normally contains the code that creates the actual visual assets on the canvas. The defining characteristic of the draw function is that by default, the code within it is repeatedly executed for as long as the sketch is active. This aspect of its behaviour makes Processing ideal for the creation of animations. Many of Processing's built in commands and functions deal specifically with drawing two and three dimensional primitive shapes such as ellipses, lines and rectangles, and monitoring and responding to user input through devices such as a mouse or keyboard. As the draw loop updates the contents of the canvas at a high frame rate this allows for animations which can respond very fluidly to the user's actions, suiting my

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project's needs particularly well.

In keeping with Processing's open source status, its I.D.E. also provides the ability to import a large number of free user-created libraries, which can enhance and customise the basic program's functionality greatly. These provide many options such as compatibility with external hardware including the Arduino and Kinect systems, and the enhanced processing of audio files. There are also libraries available which allow the production of graphical user interface elements such as buttons and sliders to further enhance a sketch's functionality. Though I would be very interested in exploring these areas further in the future they lie outside the scope of the current project. Although the prospect of adding GUI elements to the sketches certainly has potential for the moment I want the interactions presented to be simple and uncluttered, hopefully allowing the user to experience them without distraction.

Piet Mondrian

As an approach for the technique of analysing the composition of an original artwork and generating a computer program to simulate its appearance, A. Michael Noll's work provides an excellent historical template. As alluded to previously, his 1964 paper "Human or Machine: A Subjective Comparison of Piet Mondrian's "Composition with Lines (1917) and a Computer-Generated Picture" outlines the methodology he employed to simulate Mondrian's famous painting. The bulk of the text deals with Noll's analysis of the fascinating results of a survey he conducted as part of his research, which found that when presented with a picture of both the computer-generated and the original artwork, only 28 out of 100 people surveyed were able to correctly identify the simulation. Of particular relevance to this project however, is Noll's highly analytical approach to assessing the compositional elements within Mondrian's painting in order to prepare the code which would mimic them. He notes that:

> (a) The outline of the painting is a circle that has been cropped at the sides, top and bottom; (b) The vertical and horizontal bars falling within a region at the top of the painting have been shortened in length; and (c) The length and width of the bars otherwise seem to be randomly distributed (1964, p.1).

Noll then provides a detailed description of how, using this information, he went on to produce a numerical description of the picture and from this was able to write a computer program to plot the beginning and end points of the lines comprising the composition. Noll's code also contained randomised elements governing the length and distribution of the horizontal and vertical bars within

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the circular area of the canvas, and an algorithm to shorten the bars lying towards the top of the painting as per his analysis.
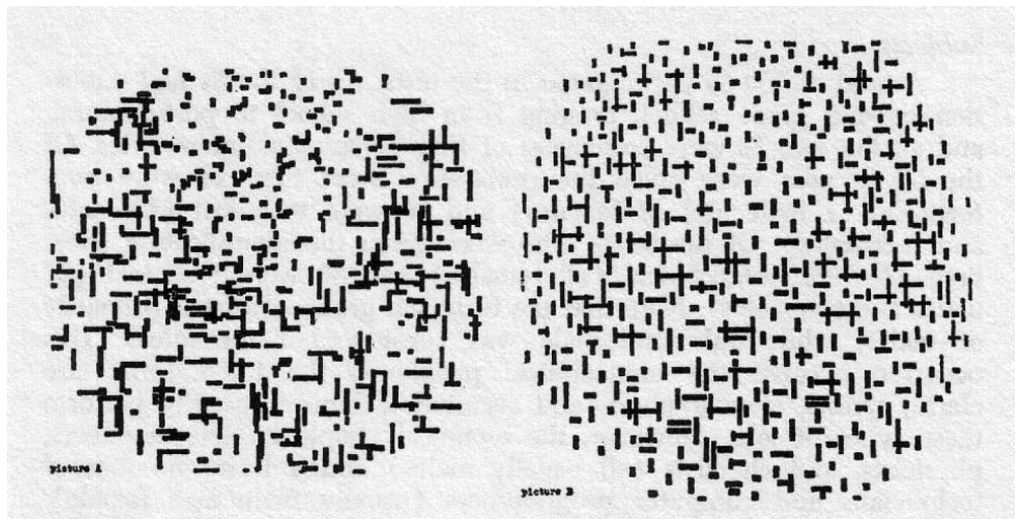

Figure 6: Computer-generated Mondrian by A. Michael Noll (1964)
(A reproduction of the original 1917 Mondrian Painting is on the right of the image)

For this project I decided to revisit an interactive Processing sketch I had previously written when I had begun to work with Processing, which allowed the user to make their own reproduction of the same Mondrian painting. With the benefit of Noll's example, and a renewed exploration of Processing I wondered if it might be possible to improve on my original effort to produce a more convincing simulation. In my original sketch I had used the program's inbuilt functions for tracking the coordinates of the mouse (*mouseX* and *mouseY*) and detecting whether or not a button was being pressed (*mousePressed*). On detecting a button mouse press, I programmed the drawing of two black bars with Processing's *line* command, one vertical and one horizontal. The positioning and length of these bars were randomised within preset parameters, the randomisation intended to produce a somewhat more organic, handmade feel to the resulting image. Also, the *frameRate* command, which controls the speed at which the image updates, was set to a low level so only a few bars were produced each second. Otherwise, they would be drawn at a very high default rate which would crowd the canvas with far too many lines producing a very unconvincing look.

While this code produced a moderately satisfactory result, in hindsight, it failed to take into account A. Michael Noll's observation that the length of the bars appeared to vary depending on their relative position within the canvas. It also always caused a cross formation to be drawn from the mouse position as it was moved, while an examination of the original painting readily reveals that many of the bars exist in isolation and do not cross over other bars oriented in the other direction. Also the

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nature of the randomisation was such that the individual lines often ended up being drawn directly adjacent to or on top of each other, producing an unattractive clumping effect completely at odds with the considered distribution of the visual elements to be found in Mondrian's original.

To resolve the clumping issue, I revisited the algorithm which provides the horizontal and vertical coordinates of the drawn lines, and mathematically forced the program to return variables which were multiples of a specific number. Through trial and error I settled on eight as the most suitable value. This effectively means that each vertical or horizontal element will always be at least seven pixels away from its nearest neighbour, thus avoiding the clumping. With prolonged drawing, the resulting grid-like structure rather gives the game away, but I still found it to be a preferable solution. In order to make the length of the bars vary in accordance to their position within the canvas I took advantage of Processing's "dist" command, which measures the distance in pixels between two given points. I used it to measure the distance from the centre point of the canvas to the current mouse position, this value then being fed into the algorithm calculating the length of the bars being drawn. While the bars' lengths are still randomised, this results in much shorter ones being drawn towards the extremities of the canvas. To prevent the program from always drawing crosses, I used Processing's *random* command to select a number between one and five. If the result is one, a function to draw a cross is called. The remaining four possibilities lead to the drawing of a horizontal or vertical bar with equal probability, leading to a more convincing distribution of the visual elements. Finally, to demarcate the circular area within which Noll had pointed out that all Mondrian's bars lie, I added a for-loop, a specific function used to repeat a particular action multiple times, to draw a series of concentric white circles of decreasing opacity in the background, forming a very subtle, soft-edged disc in the centre. Although the user is free to draw anywhere they please within the canvas, this is intended to provide a gentle suggestion of where to work.
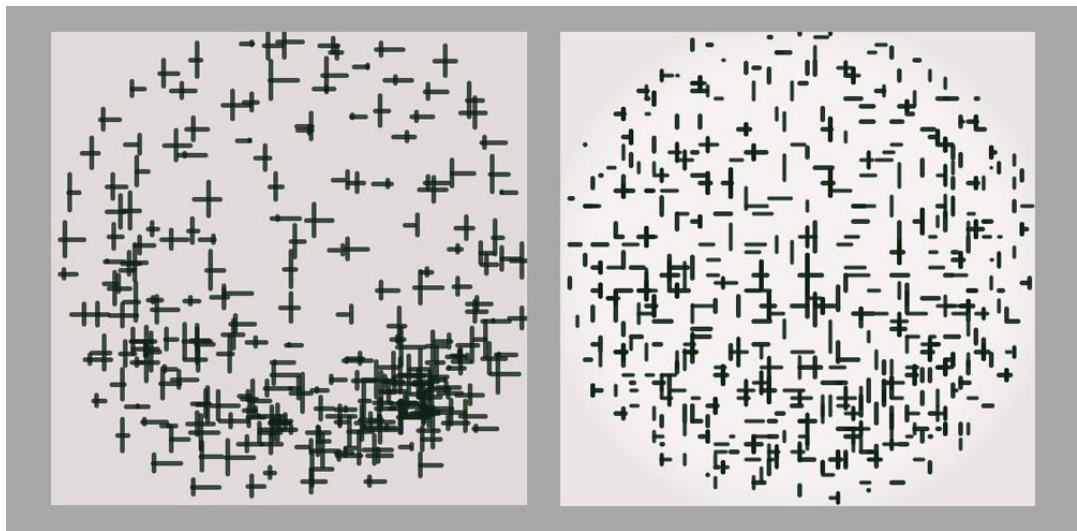
Figure 7: Comparison of original (left) and reworked Mondrian (right) Processing sketches

Jackson Pollock

Jackson Pollock is one of the better known artists associated with the Abstract Expressionism movement, based in New York during the years of the second world war. His most famous works from this period are typical of what became known as the *action* or *gesture* style of painting, the name deriving from the very clear evidence of the physical mark-making processes which the artists employed as they worked. In Pollock's case, this typically involved dispensing with the traditional stretcher secured to an easel, and working with large pieces of unstretched canvas placed on the floor, onto which he would drip paint from brushes or sticks.
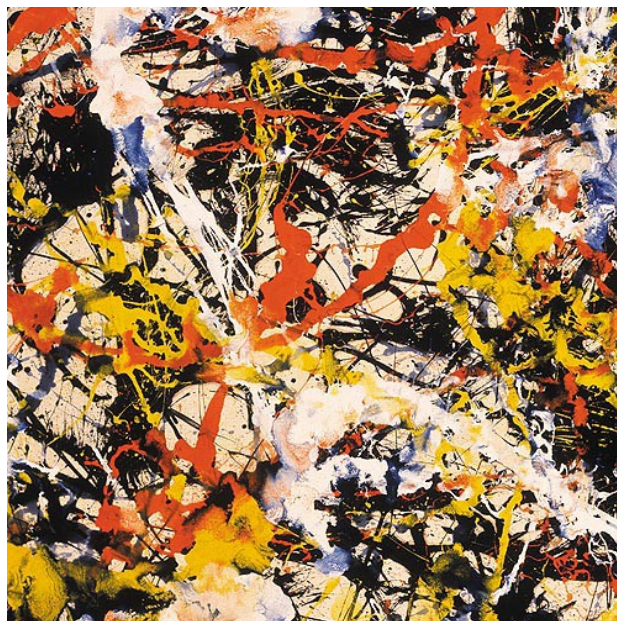

Figure 8: Detail of *Convergence* by Jackson Pollock (1952)

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On examining the methods of paint application in Jackson Pollock's later period drip paintings, it appears that broadly speaking, there are two major approaches at play. Firstly, there are passages of very broad, almost violent paint-work, where the paint appears to have been mixed to a relatively thin consistency and dripped or splashed in large volumes onto the canvas from a height with vigorous, rapid arm movements, as evidenced by the particular trajectory of the trails of colour and the presence of numerous spots and blobs of paint around them. Secondly, there are areas where the paint appears to have been mixed to a greater viscosity and elasticity, and when released from the brush was allowed to spiral its way onto the canvas below, the twists and turns of the path traced being the combined result of Pollock's own movements and the laws of physics acting upon the paint. In approaching the design of the Processing sketch to simulate this style of mark-making, I decided to attempt to replicate both approaches and allow the user to employ them by moving the mouse while holding the left and right mouse buttons respectively.

To emulate the more violent, drippy style of paint application I initially found that the most promising approach was to have the program plot a series of points placed randomly around the current mouse position, which were joined together to form a continuous chain of lines as the mouse was moved around the canvas. While this was successful in replicating the erratic, random nature of the painted line, the result had a very angular, geometric quality hardly consistent with a flowing liquid. Thickening the drawn lines helped somewhat – in cases when the mouse was stationary or moving slowly they were drawn over each other with enough rapidity to disguise the distracting angular zigzagging. When the mouse was moved at speed however, the randomness still caused an obvious and unattractive elbowing from one point to the next.

Fortunately Processing has several in-built functions to deal with the data generated by mouse interaction. By comparing the current mouse position with its previous recorded one, it's possible to arrive at a value for the speed of the movement of the mouse pointer at any time, and assign this value to a variable. It was possible to feed this variable back into the loop which generated the random points from the mouse position. At higher rates of movement, this speed variable effectively cancels out the random element and draws a smooth, continuous line from one position to the next, making for much more convincing paint behaviour. For added authenticity, it was also applied to the thickness of the line, resulting in a thinner line at higher speeds, which would somewhat mimic reality. Finally, a series of ellipses were randomly generated from the mouse position to simulate blobs of paint splashing from the points of impact of the paint flow. These were again tied to the mouse speed. At rest and low speeds they were at their largest and most scattered, while at higher speed they were smaller and more tightly grouped, effectively disappearing at high speeds where the

reduced paint flow wouldn't give them the chance to form.

Figure 9: Example of *Pollock* painting effect assigned to the left mouse button

The spiralling movement of the thinner trails of more viscous paint proved to be more difficult to mimic. Several approaches were tried; the plotting and joining of random points which had sufficed previously for the more gushing paint-flow simply didn't describe the distinct curvilinear movements at play here. The eventual solution was to generate an animated sequence describing the path of the paint and feed it to the position of the mouse when the relevant mouse button was pressed. The distinctly non-digital technique of drawing the paint's path out on a piece of improvised graph paper and writing down all the coordinates of the points was used.

Figure 10: Diagram of coordinates for *Pollock* paint flow assigned to the right mouse button

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These points were stored in a numerical array, the values from which are combined with the mouse position as it moves. Since the animation loops continuously, and its starting and finishing frames match up, the effect is reasonably convincing. As before the thickness of the line is tied to the speed of movement, and a far subtler version of the blobbing algorithm is used to better sell the illusion. The colours that appear during the painting action in both cases are randomised, based on a selection of nine which typically appeared in Pollock's canvasses.
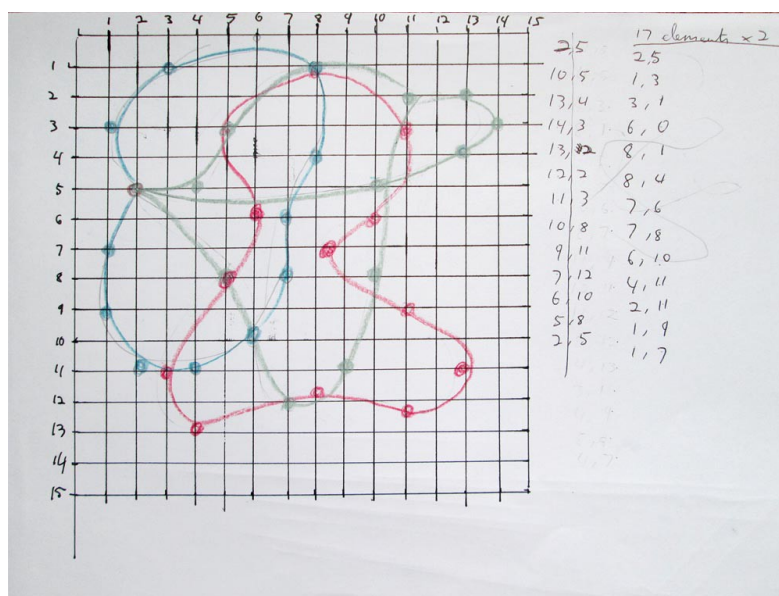

Figure 11: Example of *Pollock* painting effect assigned to the right mouse button
(on the left image, the drawn lines are greatly enlarged for clarity)

Agnes Martin

Agnes Martin's work is typified by delicate pencil drawings or monochromatic ink washes on paper, which often consist of arrangements of parallel lines or grids. They have a subtle, contemplative quality to them, and when viewed from a distance the delicacy of her technique causes the imagery to appear to dissolve, fading almost to the brink of visibility (Foster et al, 2004, p.400).
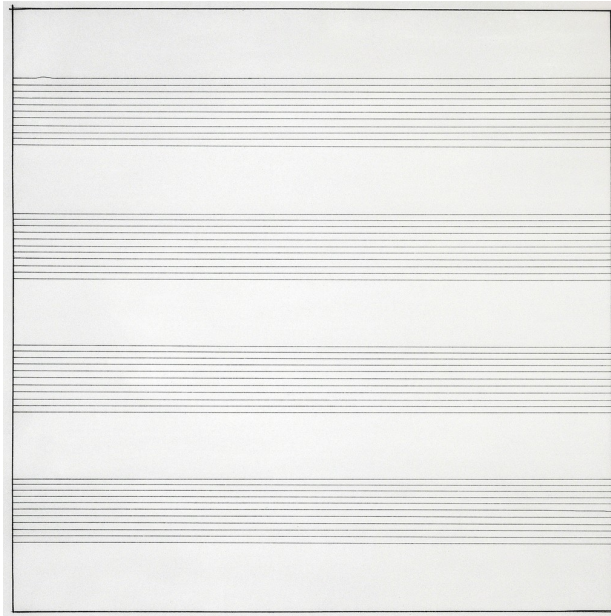
Figure 12: *Untitled #10* by Agnes Martin (1990)

In order to produce a Processing sketch to mimic Martin's style, I decided to have the program produce three drawings which I felt served as approximate archetypes to represent her style, each one being rendered by its own function. The program allows the user to move the mouse around the canvas to alter certain attributes of the drawings, while clicking a mouse button increments a counter variable which cycles the view between the three. While varying somewhat in their particular compositions, each drawing reacts in a very similar way to the user's input. As the drawings are mostly made from collections of horizontal or vertical lines of the same length, it was reasonably straightforward to write the code to produce one line, and then set up a for-loop to repeat this line at regular intervals across the canvas. In one drawing, where a series of tightly-grouped horizontal lines had varying lengths and starting positions, I drew out a series of points on graph paper, noted the coordinates and stored these in a numerical array. I then had a for-loop use these coordinates as the starting points of the lines, and the same data was manipulated to calculate their respective lengths.

The sketch reacts to two types of mouse movement. As the mouse is moved up and down the canvas the lines grow incrementally thinner or thicker, and as it travels left and right the lines become darker or lighter. This is achieved by manipulating the two commands *strokeWeight* and *stroke* respectively. As the mouse is moved vertically, its position is monitored and used to generate a variable which is fed to the strokeWeight command. The higher the mouse position, the larger this number becomes resulting in a thicker line. The mathematics handling this process was tweaked in order to provide an acceptable range of movement. Similarly, the mouse's horizontal position is used to provide a variable to the stroke command which controls the colour of the drawn lines. The range goes from

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black on the extreme left through to very light grey on the right. Additionally, the array used before to determine the line lengths is called upon again, values from it being taken and added to the "stroke" variable in all drawings. This provides a small variation in the tonal value of the individual lines as they're drawn. It's a subtle variance but on the lighter tonal ranges it provides a slightly more organic, hand-drawn feel.

With the range of values available, it's possible to produce a drawing which is composed of thick dark lines or fields, producing a blocky, geometric effect entirely unlike Martin's work. However if the tone of these lines is then lightened towards the value of the background colour, the characteristic delicacy returns, producing something perhaps not unlike her works which feature fields of ink washes. As the for-loops completely redraw the entire canvas on every frame, the overall effect of the mouse movements on the drawings has quite a smooth, analogue feel. The background is set to a pale yellowish colour to simulate the tone of the drawing papers Martin typically worked on, and to provide enough contrast with the lines drawn over it.

Figure 13: The range of imagery available in the Agnes Martin sketch

Mark Rothko

Like Pollock, Rothko was a leading figure of the Abstract Expressionism movement in New York, but was associated with another strand called colour-field painting. The canvasses typical of this style were characterised by expansive, saturated fields of colour which dominated the composition, intended to induce a meditative state of contemplation as the works were viewed. Rothko's approach was to divide his canvasses into two to three very large areas of intense colour, roughly rectangular, perhaps punctuated by one or more narrower bands. The edges of these areas were painted in a very diffuse manner, the layers of paint underneath being partly visible, which on prolonged viewing makes the fields of colour appear to float and shimmer, making for a very transcendent, affective viewing experience.

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Figure 14: *White Center (Yellow, Pink and Lavender on Rose)* by Mark Rothko (1950)

In approaching coding a Processing sketch to simulate Rothko's work, the main functionality I wanted the program to have was to allow the user to click anywhere on the surface of the canvas and produce a field of colour, randomly chosen from a limited available range which Rothko typically used. The left mouse button was to produce a large field, and the right was to draw a much narrower band of colour. These fields of colour were to have soft, diffused edges, and when placed over each other were to leave some evidence of the layers underneath to better mimic the behaviour of real paint and provide some chromatic subtlety.

To achieve the fields of colour, I first experimented with using a for-loop to generate a series of rectangles nested within each other, centred on the position where the user clicked the mouse, the loop working its way from the largest size to the smallest. The opacity of the individual rectangles was set to a low value, so that towards the centre, as more rectangles were layered over each other, the opacity accumulated to form more opaque colour. This was successful in producing rectangular fields which faded towards the edges, but the overall effect was very regular and suggested nothing of the painterly texture found in Rothko's work.

The eventual solution required more complex coding and a lot more work on the computer's processor's part but gives a somewhat more satisfactory result. When the user clicks the mouse, a series of variables are generated which define a rectangular boundary around the mouse's current

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position. This boundary has a randomised element built into it which ensures a slightly different size of field each time. Then, an erratic, twisting line is drawn from the mouse's position, the path of which is randomly generated, which bounces around inside the rectangular boundary, eventually filling it up with colour. In terms of the coding, this is achieved as follows. When the mouse is pressed, its coordinates are stored as variables, the dimensions of the bounding box are decided, and values generated and stored for its top, bottom, left and right edges. A separate function is called once which decides which one of the predetermined colours will be used. A for-loop is then initiated, which runs until the required level of colour coverage is reached. The loop calls a function which generates two random values, constrained within a predefined limit, and these are combined with the coordinates of the last mouse position to plot the position of a new point. A line is drawn between the two positions, and the loop runs again. In this way a continuous line is generated as the for-loop runs its course. Also written into the loop is a series of if-statements which monitors the current position of the line. If it strays outside the boundary rectangle, the next coordinates are altered in the opposite direction, "kicking" it back inside.

Figure 15: Randomised line traced by drawing algorithm in Rothko sketch
(greatly enlarged for clarity)

The lines are very fine and are set to a very low opacity, so that the cumulative effect of many laid over each other can produce a variety of transparencies over the field, allowing successive colours to be seen though each other to an extent. The left and right mouse buttons produce large fields and narrow bands respectively. The coding for both cases is essentially the same, only the values for the size of the bounding box and the number of lines required to be drawn are different. After considerable tweaking of the values to get an optimal result, I decided it takes thirteen thousand individual lines to produce a band, and forty thousand to make a decent larger field. This of course

requires considerable work from the host computer, but experiments with reducing the number and compensating with thicker and more opaque lines produced quite ugly results. I hope to discover a more processor-friendly approach to rendering this sketch in the future. Due to the erratic, randomised nature of the path taken by the line drawn, the overall effect gives the variation in texture I was after, as well as the diffused edge. If the user wishes to start over, they can press a key which will clear the canvas and generate a new, randomised canvas colour on which to work.
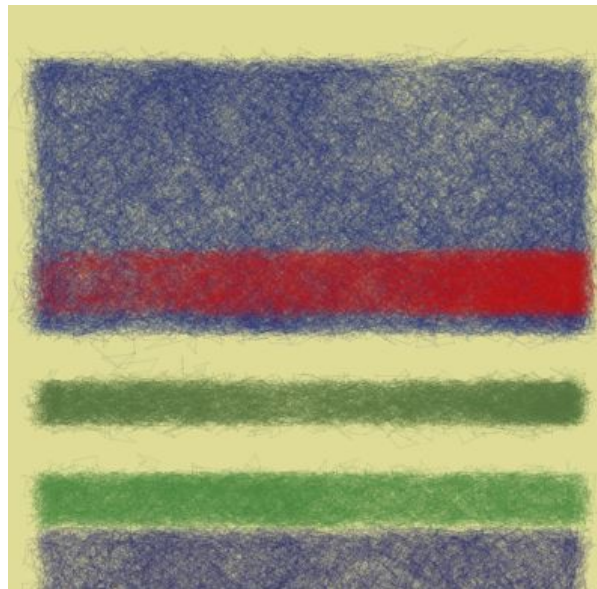

Figure 16: Overlaid colour field effect produced by drawing algorithm in Rothko sketch

From the user's point of view, I have attempted to design this sketch to be quite an aesthetically pleasurable interaction. If they wish, they are able to place successive fields of colour directly over each other and observe the chromatic effects of their layering. There is a deliberate element of chance involved in the making of each image, particularly as the user cannot predict what colour will be produced next, which I hope will make for a more engaging experience. As the sizes of fields produced are somewhat randomised, a slightly smaller field will often be placed onto a larger one, allowing the edges to protrude from underneath, a technique that Rothko often employed himself.

Kazimir Malevich
Malevich's paintings from his Suprematist body of work are typically characterised by the presence of a light-coloured background, over which have been painted a number of basic geometric forms such as squares, rectangles, trapeziums, lines and less frequently circles and triangles. The works range in complexity from having one or two shapes, to much more complex compositions featuring perhaps

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dozens of individual shapes, grouped in clusters around the canvas, all of which appear to "float" in the space within the picture's frame. In these works Malevich tended to work with a limited colour palette of quite intense hues, including the primary colours of red, yellow and blue and several others.

Figure 17: *Suprematist Painting* by Kazimir Malevich (1916)

In approaching a Processing sketch to simulate a Malevich painting, the main learning experience I wanted the users of the sketch to gain was an appreciation of these relationships Malevich established between the painted elements in terms of type, colour and size. I wanted to achieve this by allowing them to position the mouse on the canvas and click to draw a shape on it, larger shapes assigned to the left button and smaller ones on the right. The type of shape, its colour and several other attributes were to be randomised to provide a gaming aspect to the interaction, but I also wanted the program to exhibit certain behaviours when it came to the placement of new elements which would be more in keeping with Malevich's style. This is also the only sketch in which I wanted to provide the user with the ability to undo their previous actions, so that having placed an element on the canvas they could decide if they were happy with its relationship with the others and change it if necessary. Despite its very minimalist aesthetics, the functionality required of this code made it perhaps the most complex piece of programming in the project.

As with the other artworks dealt with in the series, the first step in the process was to examine a number of artworks typical of Malevich's Suprematist style to determine how the sketch should

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behave. In addition to the description above, several other factors become apparent while comparing these artworks. In the more complex pieces, Malevich would regularly paint a small number of larger, dominant shapes, apparently rotated at various angles, around which he would place clusters of smaller elements. The shapes comprising these clusters regularly featured similarly coloured and sized shapes, grouped quite tightly, set at angles rotating in increments of about 45 degrees to each other.

The first task was to write functions to handle the drawing of the basic shapes the program is capable of generating. There are only three in total: a circle, a rectangle, and a line (actually an elongated rectangle). These are all easily handled by Processing's library of commands which deal with 2d primitive shapes. To add variety to these basic forms, a number of other attributes were created, assigned to variables and added to the shapes at the drawing stage. These changeable attributes include the shapes' colour, degree of rotation, and a set of scale variables to perform resizing in both the horizontal and vertical axes. The position of the mouse pointer in both axes is also recorded for all shapes. This last piece of information is particularly important in that it allows the program to calculate the distance between the current and previous shapes, and store this information as a variable. A series of arrays was set up, one for each of these properties, to record all the variables generated as the user interacts with the program.

With this basic structure in place, it then remained to assign behaviours to the different mouse and keyboard actions available to the user. When the left mouse button is pressed, a large shape is generated. In many of the original paintings, the largest shapes don't appear to follow any particularly recognisable patterns of placement or colour. Therefore a random shape and level of rotation is chosen, as well as variables for scale which are randomised but still constrained to larger values. A random colour is chosen from a predetermined set of six based on actual colours the artist typically used. Once all these values are determined, their respective variables are appended to their arrays and then sent as arguments to the main drawing function, which determines where and how each shape is drawn to the canvas.

When the right mouse button is pressed to draw a smaller shape, a similar process occurs but with a few added behaviours. As before, a random shape is selected, but this time the circle is excluded from the choice as it rarely seems to occur in a smaller form in Malevich's paintings. In general, as before, the colour and rotation is selected randomly, and the scale still randomised but set within a smaller range. However, the distance variable now comes into play, measuring how far the user has moved the mouse since placing the last shape. If the distance is within a predetermined smaller

range, arrived at through trial and error, a series of conditional statements affects the subsequent decisions made. The colour from the last shape will be retained. The scaling will be set to a significantly smaller level, and the rotation will be allowed to change only in increments of 90 degrees, with a small variance added to give a more organic feel. This goes some way towards reproducing the look of the clusters of smaller elements found on many of the Suprematist paintings. On larger distances the original randomisation is restored.
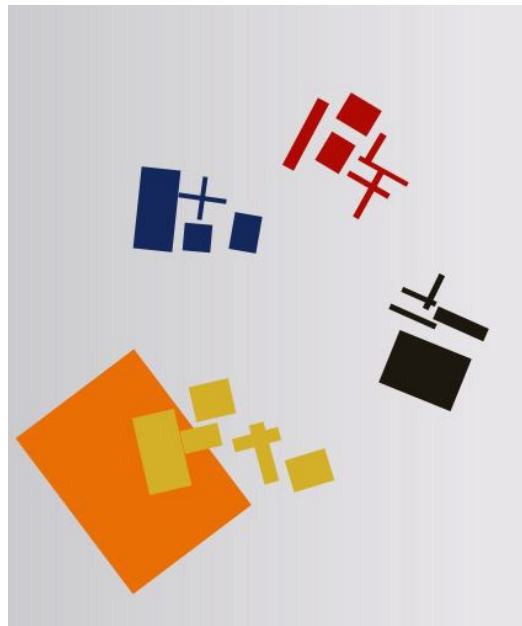

Figure 18: Demonstration of the grouping behaviour in the Malevich sketch

Should the user decide to step backwards at any time, a key press causes all the arrays to be decremented by one place, removing their last entries, and the entire image is redrawn minus the undesired item. For a slightly more authentic feel, a for-loop is used to draw a series of rectangles of decreasing opacity in the background which forms a subtle gradient without requiring too much processing power.

Bridget Riley

Bridget Riley is one of the better known exponents of the Op art movement, a form of abstraction which is heavily concerned with the creation of optical illusions, typically created in a very minimalist style and often painted in black and white. It exploits the workings of the human visual system to produce images which appear to vibrate, warp or swell the two dimensional space of the canvas or generally create the impression of movement.

"Movement in Squares" is a well known Riley work dating from 1961. The painting consists of a

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patterning of alternate black and white squares, rather like a chess board, which for a large section of the surface area remain locked in a regular grid. Towards the right hand side of the painting however, there is a section along which the width of the squares have been incrementally reduced from left to right until they read as vertical lines, before being being returned to their normal size again. This simple manipulation of the squares' dimensions produces a very convincing impression that the painted surface has been curved in three dimensional space away from the viewer to the point where the lines are narrowest.

As this painting communicates a strong sensation of movement of its surface to the viewer, in order to produce a virtual interaction based on it I thought it might be interesting to let the user experiment with creating actual movement. I therefore wanted to create a Processing sketch which would allow this area to be moved laterally across the surface to a new position, the surrounding rectangles being resized accordingly.

The first task was to create some code to draw the grid of black and white squares. This was achieved by having a for-loop draw a series of adjacent squares across the canvas until they reached the edge. This loop was nested inside another for-loop, taking this line of squares and repeating it from top to bottom. Slightly trickier was creating the alternating black and white colouring of the squares. This problem was eventually solved by creating a switcher variable, which was initially assigned a value of one. At the end of the code for the first loop, having drawn a square, the value of the switcher is multiplied by -1, causing its value to alternate continually from 1 to -1. At the start of the loop, this variable is checked with a conditional statement. If its value is 1, the fill colour of the next square is set to white, otherwise a black square is drawn. The same algorithm is applied to the outer loop resulting in a continuous alternating of all squares from black to white.

The narrowing of the width of the squares and subsequent widening again took some experimenting to achieve. I initially tried to write code to calculate these changes in accordance with the current mouse position and apply them to the drawing of the individual squares on the fly. Although I'm sure this is perfectly possible to achieve, my knowledge of mathematics was not quite up to the task. I had to settle for a less sophisticated solution, which involved physically measuring the actual widths of the rectangles on a reproduction of the original painting from left to right as they narrowed and increased in width again. These values were recorded and assigned to a numerical array created for the purpose. The drawing function was then amended to measure the horizontal position of the mouse each time through the loop. If the mouse is towards the left of the canvas, the point in the array from which the widths are read is set further on, effectively moving the thinnest lines to the

left. By tweaking the variables involved, it was possible to give a reasonable impression of the narrow region being dragged left and right with the mouse. A cheat of sorts, but it works well enough. Finally, I added a block of code that monitors the vertical position of the mouse, and introduces subtle shifts of colouring in the black squares as the mouse moves towards the extremities. As the level of interaction offered to the user in this sketch is quite minimal compared to some of the others, I felt this offered another small level of engagement.
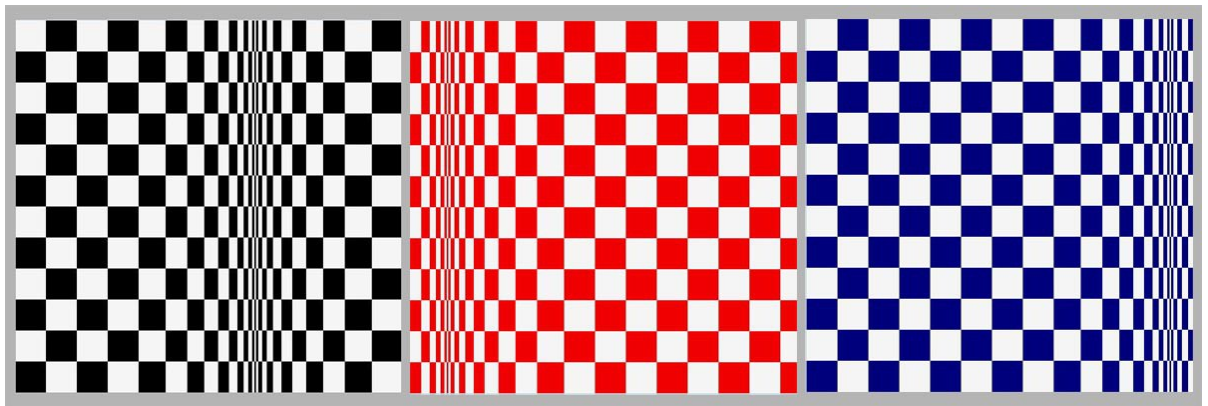

Figure 19: *Movement in Squares* by Bridget Riley (1961): sketch demonstration showing range of movement and colour

Other works from Riley's 1960s output consist of images made from series of curved lines, somewhat resembling sine waves rotated through ninety degrees. These are placed end to end to describe continuous curving trails down the picture plane, and are repeated at close intervals laterally across the surface. In "Fall" (1963) Riley increases the frequency of the curves towards the bottom of the work, producing a strong illusion of the warping of the surface, the resulting visual tension increasing as the viewer's eye works its way down the picture. An optical shimmering effect is also observed as the eye attempts to make sense of the information confronting it, exaggerated as the viewer shifts position, altering the viewing angle and distance from the work.

As with the previous Riley work, I wanted the Processing sketch to mimic the general appearance of the artwork while allowing the user's mouse movement in any direction to change the arrangement of the visual elements within it. I wanted the lateral movement of the mouse to increase or decrease the degree of curvature of the lines, allowing a transition from straight vertical bars to the degree of curvature present in the original work. I had anticipated that this might be a particularly tricky Processing sketch to write, but the animated behaviour I wanted turned out to be very suited to the software's functioning, and there are only a few lines of code in the finished program.

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The main work in the sketch is done by Processing's *bezier curve* function, which allows an s-shaped curve to be drawn by specifying a starting and finishing anchor point, together with two other control points which influence the path taken by the line between the two anchors. Though these can in practice be placed anywhere on the canvas, if they are placed on either side of a straight line between the anchor points, something resembling a sine wave is made. It was therefore reasonably easy to plot a series of bezier curves down the canvas joining end to end, the distance between them reducing towards the bottom. This done, it was straightforward to have a for-loop repeat the lines at intervals across the width of the sketch. In fact, two overlapping curves are drawn in each location, the second offset slightly more to the sides than the first. This provides a curved line that thickens towards the lateral extremities, as Riley had painted them. The start and end points of each curve always remain the same, but the two coordinates that form the control points are assigned variables and tied to the horizontal position of the mouse. As the sketch is redrawn at a high frame rate, the result is quite a smooth widening and narrowing of the curves as the mouse is moved. Also, if the mouse crosses from one half of the canvas into the other, the value of these variables is inverted to allow the direction of movement of the curves to flip from left to right resulting in a somewhat snake-like movement.

Figure 20: *Fall* by Bridget Riley (1963): range of movement produced by sketch

Finally, as the vertical mouse direction had not yet been used I tied its value to the strokeWeight command, which governs the thickness of the drawn lines, and also to the drawing loop, altering its increment value. As the mouse is moved down the canvas, these alterations cause the lines to be drawn both thicker and further apart, allowing the user to experiment with the significant perceptual changes that result.

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Overview of the Technical Aspects of Building the Website

Once the Processing sketches were written and all working satisfactorily offline, it was necessary to embed them into the pages of the website. A solution to doing this was offered by Processing.js (www.processingjs.org), a sister project to Processing which enables sketches to be displayed within a web page. In order to use this method, the relevant sketch and the Processing.js JavaScript file are uploaded to the server along with the HTML document and other relevant files. Within the HTML coding the Processing.js file is called from within the head section and the Processing sketch itself is then called from within a canvas element in the body of the HTML. This allows the browser to display the sketch without the need for a Java applet or Flash plug-in, approaches which are becoming increasingly unsupported by browsers. Once this process was completed for all sketches and tested online with several browsers the results were largely satisfactory, but there were a number of problems which needed to be resolved which weren't present when the programs were run offline as stand-alone applications.

In sketches which allow the user to draw freely, particularly on some interactions based on the works of Franz Kline, a consistent issue arose when a mouse button was held down for drawing and moved outside the canvas. If the mouse was then moved back inside, the drawing continued even though no button was being pressed. To deal with this I added some additional lines of code to the sketches to switch off the drawing loop when the mouse pointer reaches the edge of the canvas. Additionally on the Pollock sketch, if the user rapidly moved outside the canvas and returned while drawing, an unsightly straight line would be drawn by the program along that edge. To resolve this I added a border around the edge of the drawing area, which was continually redrawn on every frame where the mouse was detected close to the edge. The problem remains in the code, but this "frame" is drawn over it and essentially hides the issue. The Kline sketches initially displayed poor performance on certain browsers, but this problem was somewhat resolved by going through the code and turning off certain functions which had been running constantly, and only calling them when strictly necessary. There were several other problems, many of which were resolved by the renaming of variables within the coding so that they were less similar to reserved variables and commands within the Processing reference library, an apparently prevalent issue.

These issues aside, Processing.js proved to be an effective way to get the sketches running online, and in the future I hope to discover more elegant coding solutions to the problems encountered. I also experimented with another sister project, p5.js (https://p5js.org/), in which the sketches are written in JavaScript and can be more directly incorporated into HTML documents online and appears

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to offer a great deal of flexibility and potential for interactivity. As HTML5 is directly compatible with JavaScript, I expect that to eventually rewrite all of the programs in p5.js may be wise in terms of future stability and browser compatibility.

Regarding the authoring of the HTML, and not having authored or published a bespoke website before, I felt it wise to keep the design and coding aspects as simple as possible. "Sams Teach Yourself HTML, CSS and JavaScript All in One" by Julie C. Meloni became a valuable resource in this process. As per the book's advice I wrote a single stylesheet in CSS for the entire site and made changes to it when necessary. Essentially, I only had to write one HTML template and slot in the content for the appropriate pages, making a few local formatting and style changes where appropriate.

<u>Discussion of Website Design & Educational Content</u>

In compiling the content for the site and giving an appropriate educational context to the interactive programs there were some key issues I wanted to address. Firstly, even though I see this as primarily an educational resource I didn't want to overwhelm visitors to the site with too much textual information. I wanted what written information there was to be succinct and to serve the other elements, interactive and visual, rather than compete with them. Secondly, I wanted the exercises to be arranged in an order which would introduce topics gradually, building on one another in an iterative way, without introducing too much new information at a time (Beetham, Sharpe, 2007, p.15). Finally, careful consideration needed to be given to the arrangement of the various panels which were to hold the content, to provide a viewing environment which was user-friendly and uncluttered, but also provided a reassuring consistency from page to page.

In terms of layout, I decided on an initial home page introducing the site's content and its aims, and a subsequent set of similarly designed pages containing the pedagogical content, each dealing with a different artist and set of topics. There is a horizontal navigation area under a large header image containing links to all pages. Under the navigation bar on each page there is a brief introductory paragraph on the featured artist, outlining their practice and major art movements they may have been associated with. Below this there are two adjacent panels. The left-hand panel contains a small reproduction of one of the artist's works, and a few paragraphs describing the piece and elaborating on some of the points raised in the introduction. To the right is a wider panel containing the actual Processing sketch, along with some simple instructions on its use. The panels remain side by side as I feel it is important to have the original artwork within the lateral field of view as a reference while engaging with the Processing sketch, an approach which has been shown to be particularly effective for learning (Beetham, Sharpe, 2007, p.33). As well as being larger, the interactive panel is differentiated from the others in styling terms with its own background colour and a subtle border, in order to help indicate its particular function. Finally, below this area is a discussion section which typically explains a commonly used art term or two, and poses a list of topics for consideration, to generate discussion particularly in a group context.

Regarding the art historical content, the presentation of the artists' works is in rough chronological order, but exceptions are made in cases where I felt the concepts being introduced by each work warranted an adjustment. For example, Kazimir Malevich appears after Josef Albers, while in reality Malevich's Suprematist paintings preceded Albers's "Homage to the Square" series by several decades. Albers appears first as both his and Piet Mondrian's work tended to feature visual elements

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arranged only in horizontal or vertical orientations, therefore they are dealt with first. As Malevich introduces elements set at various angles, a dramatically different compositional approach, I wanted to emphasise the importance of the distinction and so placed his page afterwards. It should also be emphasised that the site in no way attempts to provide a comprehensive overview of the history of abstraction in visual art. As a practising artist and art educator I have a decent working knowledge of the area but I am not a qualified art historian and such an endeavour lies outside the scope of this project. Besides this a very extensive body of scholarly writing exists on the subject for those seeking further knowledge. I merely hope to introduce a handful of key concepts which may hopefully provide a "way in" to the subject matter and encourage visitors to the site to explore the field further.

Although the website in its current form appears to function reasonably well, I see it as a starting point on which I can build. Although as yet there has not been time to conduct any extensive form of feedback, I did recently have a brief opportunity to demonstrate it informally to a group of primary school teachers as part of a training session I was conducting with them, and provide them with the website address. I was particularly interested in whether they felt the site could be of use in their own classroom situations, given the relative ubiquity of interactive whiteboards in classrooms now. At the time of writing I have received some useful responses, indicating that although the interactions would likely be suitable, it would be necessary to simplify the written aspects to make them more appropriate for younger groups. I will therefore consider producing alternate versions of the resource to make it more scaleable for a wider range of visitors. Interestingly, I have also been asked if I would consider producing similar interactive resources to aid in the teaching of other subjects such as mathematics, to explore concepts such as the construction of lines and angles, the recognition of geometric shapes and tessellation. These are areas I would be very interested in pursuing.

<u>Discussion of Educational Topics</u>

Each of the interactive sketches presented on the site is designed to incorporate a distinct "possibility space", or range of potential configurations which are available for the user to explore (Bogost 2007, location 959). As this possibility space is derived from an analysis of the design characteristics of the relevant artwork, it is hoped that an understanding of the artist's approach may be gained from the interaction. Though not explicitly stated, it is my hope that through interacting with these programs visitors will have an opportunity to reflect on how their own versions of the artworks compare, perhaps not always favourably, to the originals. In this way it is hoped that over the course of an extended period spent with the site, a fresh evaluation and appreciation of the aesthetic merits of the featured works may be encouraged. As much as possible I have attempted to arrange the Processing sketches on the website in an order that allows visitors to be presented with a range of differing interactions as they proceed, both to ward off repetition and to keep the interactions as appropriate to their respective artworks as possible.

<u>Piet Mondrian</u>

Dutch painter Piet Mondrian as the first artist to be introduced, primarily because he was one of the very first to embrace abstraction, but also because of his strong association with the Dutch "De Stijl" movement. As this movement's emphasis on clean lines and simple functional design have had an influence on design that can still be keenly felt today, I expect even those unfamiliar with his work will feel an affinity with it on some level. The introductory section briefly charts Mondrian's gradual progression from representational painting to abstraction, as his paintings of trees became progressively more abstracted, eventually morphing into compositions made solely from horizontal and vertical black bars (Moszynska 1990, p.50). I feel this background is important as some understanding of where abstraction "came from" may help remove a barrier for those who may be bewildered by it or sceptical of its merits.

Two paintings are presented and discussed, "Composition with Lines" (1917) and "Composition II in Red, Blue and Yellow" (1930) and are given accompanying interactions. The interaction for the former painting allows the user to effectively draw their own version of the piece with some randomised behaviour built into the code, allowing for as much deviation from the original painting as the user desires. It also accustomises the user to some interactive behaviours which will be used again in later exercises. The interaction for the latter work is quite different in nature, allowing for somewhat less decision-making on the user's part, as they are limited to clicking on individual parts of the image to cycle through five available colours. The original colour arrangement can be reverted to at the press

of a key, but otherwise the composition cannot be changed.

Two fundamental design concepts are introduced on this page. "Composition with Lines" is used to illustrate the principle of figure and ground in painting. The ground of the painting generally refers to the featureless background colour of the canvas, if discernible as such, onto which other distinct visual elements are subsequently added. These other elements are collectively considered to be the ground of the painting. The success of many artworks depends on the artist's handling of the specific relationship between these two properties, so the opportunity is taken to illustrate the concept early on. In terms of the interaction, the user is initially presented only with the ground of the painting, therefore any mark they make on the canvas will constitute the figure, hopefully resulting in a decent grasp of the concept. The accompanying questions encourage a closer consideration of Mondrian's particular approach to handling figure and ground, and also on his arrangement and distribution of the visual elements in the work, and how they relate to the potential suggestion of three dimensional form in the piece.

In the later 1930 painting "Composition II in Red, Blue and Yellow" the opportunity is taken to examine some specifics of the development of Mondrian's style in the intervening years, particularly the radical changes in composition and the significance of his introduction and use of colour. The concept of the picture plane, the rectangular surface bounded by the the work's frame or outer extremities, is introduced, a property which is present in all two dimensional artworks, not just abstract pieces. The asymmetrical nature of the work is noted, as is the tendency for compositional structures composed of horizontals and verticals to produce a sensation of stability, as alternative approaches will be explored in later exercises. The interaction for this work allows the user to explore the specific colour relationships within the piece and observe how their own combinations compare to the original, and the questions encourage a consideration of how the use of colour relates to the previously discussed concept of ground and figure.

Josef Albers

The next artist in the series to be discussed is German painter and printmaker Josef Albers. His "Homage to the Square" series, painted from 1949 onwards, remains his most enduring legacy and forms an authoritative study of the properties of colours and their relationships within a composition. Building on the introduction to colour from Mondrian's later work, the interactive sketch allows the user to experiment with Albers's nested squares format by changing the colours in each of the four sections within the composition at will. The Albers program allows for the generation of a far greater range of colours than the five offered before, and the user is encouraged to experiment with setting

them to different values to observe how their relationship to each other potentially creates different moods and suggestions of spatial depth within the painting.

The concept of serial art, in which an exhaustive number of variants of a single design template are explored by the artist, is also raised here, as Albers constitutes perhaps the most notable exponent of the approach. The strict lateral symmetry of the composition is also noted and contrasted to the previous Mondrian work, the user invited to consider the reasons for favouring one approach over the other.

Kazimir Malevich

Russian artist Kazimir Malevich is the next artist to be considered, and it is with Malevich that the first deviation from exclusively horizontal and vertical forms is encountered. The numerous geometric elements placed on his canvasses in various orientations make for a far more dynamic feel to his works, unlike the relative solidity encountered before, and an entirely different approach to the suggestion of spatial depth. Key also to his approach is how he manipulates his shapes in terms of their groupings, specific shapes, colour, proximity and scale to form a sophisticated series of perceptual relationships with one another, effectively forming a type of universal visual language. For example, a small square may exert a strong influence on a large line on the other side of the canvas because they are the only shapes painted in the same colour. These are the issues I have attempted to encourage the user to explore while interacting with the Malevich Processing sketch, given the specific behaviours it exhibits described in detail elsewhere in this text.

As the generation of the visual elements are to a large extent randomised to maintain a gaming context, I felt the addition of an undo function in this sketch was vital. This is to allow the student to make more considered decisions in composing their Malevich, at each point deciding whether the specific shape they have been dealt enhances or weakens their composition and reacting accordingly. The questions provided at the end are designed to encourage further exploration of these issues.

Agnes Martin

Agnes Martin's page and accompanying interactive sketch is designed to form a change of pace and intensity from the preceding Malevich exercise. Here, the nature of the interaction is a more limited but hopefully somewhat relaxing experience. By moving the mouse around the canvas the user attempts to find their own interpretation of a perceptual *sweet spot*, a region where the contrast between the figure and ground is reduced to the point where it mimics the serene luminosity found in Martin's delicately pencilled works. As Martin often worked with grids and bands of horizontal and

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vertical lines, the concept of deductive composition is introduced, an approach whereby the orientation of elements in the artwork is deduced from the edges of the canvas, as already encountered with Albers and Mondrian (Foster et al, 2004, p.682).

On the Processing sketch, it's possible to switch between three archetypal versions of Martin's compositions to illustrate the differing forms the deductive approach may take. A further consideration of the figure-ground relationship is suggested at this point, as unlike in the Malevich and Mondrian works, where a strong differentiation between the two is evident, the contemplative serenity of Martin's work comes from the figure appearing to almost merge into the ground. This is particularly evident when viewers of the original works move from a position close to the painting's surface, where the individual fine lines are easily discernible, to viewing the work from a greater distance. It is this physical transition and resulting shift in the viewing experience which the program attempts to simulate.

Mark Rothko

Abstract expressionist painter Mark Rothko is dealt with next, a choice which seems apt as his large fields of colour with their diffused, softened edges produce something of a similar sensation of nebulousness as Agnes Martin's work. Rothko is introduced as a painter who didn't use straight lines and geometric elements to compose his paintings, the contrast in this approach to the artists previously discussed is highlighted for comparison. The extremely large size of his paintings and the resulting sense of envelopment and contemplation this communicates to the viewer is also discussed.

The Processing sketch, as with the Malevich before it, features a considerable element of chance. The student is fully in control of where "painted" elements are placed on the vertical axes of the canvas, and can choose to place a large field of colour or a narrower stripe, but the details of actual size, colour and relative opacity is randomised by the code. The ground colour of the painting is also selected from a large range of possibilities and a new colour can be chosen at will. Unlike the Malevich, where each newly generated element completely obscures those underneath, the drawing algorithm here allows the fields underneath to partly show through those placed on top, allowing for a different reading of the colour relationships between visual elements on the canvas. This approach was often used by Rothko in his canvasses, achieved by overpainting with pigments of varying transparency, lending the works a shimmering, luminous quality. The user is invited to explore these relationships for themselves by continually adding fields of colour over each other and considering the resulting image.

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While the computer simulation can't hope to match Rothko's judgement of subtle modulations of tone and colour, it is hoped that something of the principles of his methodology comes across. The concept of colour field painting, of which Rothko is an excellent exponent, is then introduced and briefly explained. The questions in this section invite a consideration of Rothko's and Malevich's work in terms of their differing approaches to the handling of space within their compositions, and the particular mood communicated by Rothko's paintings is discussed in terms of the others artists.

<u>Bridget Riley</u>

Stylistically speaking Bridget Riley's work stands as something of a departure to the artists previously discussed, as the Op art movement of the 1960s with which she is associated was concerned with providing its audience with a fundamentally different type of viewing experience. Op art relies for its impact on the artists knowledge and deliberate manipulation of the human visual system to produce works which are effectively optical illusions. The aim of the activities on this page is to explore this idea in terms of topics which have already been introduced, specifically the figure-ground relationship and use of hard-edged geometric elements, and attempts to highlight the differences with which Riley employs them.

Fundamental here is the concept of the "energy" which appears to emanate from Riley's canvasses, a somewhat difficult concept to pin down but one which should be obvious to anyone who has viewed an Op art work and experienced the sensations of vibration, movement and even dizziness which may induced by the experience. The written content focuses on the methods of repetition and variation Riley used to convey this energy in the work and importantly, how she designed some areas of her works to be "quieter" than others so the viewing experience is not overwhelming but more nuanced and balanced. As with the Agnes Martin sketch, the interactions provided here are more limited in scope allowing, in the case of "Movement in Squares", for the repositioning of the more active areas to observe the effect this has on the symmetry and balance of the overall composition.

In "Fall" the frequency, thickness and degree of curvature of the geometric elements can be adjusted from those found in the original work within quite wide parameters, which appears to have a significant effect on the levels of perceived movement and vibration given off by the piece. The provided questions invite a closer look at Riley's particular use of contrast in the figure-ground relationship, as the effect of her exploitation of this property is probably the most extreme yet encountered. The student is also asked to compare her method of the suggestion of spatial depth to that employed by Malevich and Albers, as her apparent warping of the surface of the canvas by optical means is a no less effective, but qualitatively different approach to the others.

Franz Kline, Jackson Pollock

Franz Kline and Jackson Pollock are the last two painters to be considered, and are grouped together because they are both considered to be action painters, a distinct branch of the Abstract Expressionism movement. Though their physically energetic, gesture based approach to painting sets them apart from the other artists discussed so far, some of the concepts already discussed are worth revisiting in the context of their work.

Kline is dealt with first, and a distinction is drawn between action painting and colour field painting, the other major branch of Abstract Expressionism represented by Mark Rothko. Kline's creative output is of particular value here because his mature paintings are very involved with the concepts of positive and negative space. This is related to figure and ground, but more concerned with how the viewer's perception would differentiate various regions of the painting into the more significant *subject* areas, which are positive, and the remaining negative surrounding space. As the surface of many of Kline's abstract works is divided roughly into equal amounts of black and white, there arises the interesting question of which of the two should be considered to play the main part in forming the design. Most people tend to identify the black as the active agent in the composition, with the white functioning as background, but Kline himself insisted both colours were of equal importance (Elger 2008, p.86). The interactive sketches are designed to illustrate this principal as they present two blank canvasses, one with a black background and the other white, each featuring tools allowing the user to paint freely with the opposite colour to the background. The user is encouraged to design their own image and reproduce it on both canvasses, with the blacks and whites in the same areas in both cases. Having painted the top image in black, it will be necessary to paint only the opposite areas in the lower image to achieve a similar composition, hopefully reinforcing an understanding of the distinction between positive and negative space. The questions included are designed to stimulate the student's understanding of the concept further, and also deal with the comparison of Kline's use of black and white to Bridget Riley's rather different approach.

Jackson Pollock is the final artist to be considered in the project, and some space is devoted to a description of the unique energy and physicality in his approach to the act of painting. The main concept to be introduced on Pollock's page is that of all-over painting, an approach where the entire surface of the canvas is treated in a roughly homogeneous manner, with little hierarchy or distinction drawn between the visual elements used. A comparison is invited in this regard to Rothko, whose division of the picture plane into large distinct fields of colour separated by narrower striped areas provides much of the compositional interest in the work. Also, the student is asked to consider a

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comparison to Bridget Riley in terms of the all-over concept. Even though there are variances in the distribution and scaling of the geometric elements in her works, I feel the fact that they are still fundamentally composed of large numbers of repeated elements warrants the comparison.

Pollock's particular skill lay in the speed and judgement with which he guided his brush, anticipating and reacting to the paint's movements and depositing it with a full awareness of the layers of other colours previously laid down, to achieve a delicately balanced series of rhythms and colour relationships. This would have required a high level of urgency and concentration, and this is the sense I have attempted to convey to the user in this sketch. As either mouse button is held down, the colour will continue to gush forward, so some momentum of movement must be maintained to prevent large areas of the canvas from filling up with paint. Also, as each subsequent mouse press results in an unpredictable change of pigment, it becomes necessary to make decisions about where to deposit each new colour so that it forms interesting relationships, in terms of harmony or contrast, to those below. Of course, this sketch being essentially a highly customised painting program, the user is completely free to produce a "Pollockish" image of anything they choose in whatever manner they like. It is hoped however, that whatever is produced, a comparison to the artists' own work may provide some further understanding of its quality and characteristics. As it is the last interactive sketch on the site, it is also designed to be rather a fun activity, and functions as a sort of reward to the student for having worked their way through all of the content.

<u>Conclusion</u>

Although this project has been a challenging one, and certainly far more time-consuming than I had originally anticipated, I have nevertheless found it to be a very rewarding experience. Over the course of my research I have gathered considerable experience in programming and website authoring, areas in which I have long wanted to improve my levels of competence. The experience gained in the Processing programming language is something I intend to build upon in the future. As well the development of further online educational resources, I intend to incorporate its usage into my own personal art practice, perhaps to develop site-specific installations which can generate imagery to respond in real time to visitors' movements. This is an area to which the language appears to be particularly well suited, as there are a growing selection of libraries available which enable it to communicate with various forms of external hardware.

Although I have long been interested in abstract art and have had an awareness of the theories which continue to inform its design and production, the particular manner in which I have had to analyse the design of the works featured in this project has had a profound effect on my appreciation of them. Having to confront an artwork which has been deemed culturally significant by numerous art critics and historians, break it down into numerical descriptions and write codified behaviours to simulate it may seem a rather strange thing for an artist to have done. It has however given me a renewed admiration of the skill, originality and sophistication with which these artists clearly made their works. It has also strengthened my belief that the gulf which can often exist between practitioners of the sciences and the arts, each sceptical of the other's validity and practices, really need not exist at all.

Furthermore, the learning and research aspects of the project have given me a renewed appreciation of the scale of the effort with which so many people develop open source digital tools, and provide extensive support to help others gain competence in their usage. This had led to a culture whereby if a resource you would like to use doesn't appear to exist, it's perfectly feasible, with a little time and effort, to attempt to make it yourself from the range of tools available. This can also lead to a positive spirit of reciprocation within which the resources developed from this process may in turn be of benefit to others.

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