Exploring the Human Visual Perception Process
to
Foster Mindful Seeing

(*Finding the Angels and Devils in the Details*)

by David T. E. Foster

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ABSTRACT

David T. E. Foster
‘Exploring the Human Visual Perception Process to Foster Mindful Seeing (*Finding the Angels and Devils in the Details*)’
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Using the principles of Iterative and Human Centred Design as methodologies, gaze-tracking equipment and techniques and analysis of writings in such areas as medical, neurological and psychological studies in the visual perception process, the principles of mindfulness and mindful meditation, Trompe L’oeil painting and camouflage, this project will observe the saccade/fixation patterns of study participants viewing multiple different photographic images in an attempt to build a database of saccade/fixation patterns.

The use of gaze tracking and high definition display may demonstrate that there is a common eye movement pattern and perhaps that the viewer’s personal visual perception system may hide or omit much of the detail in any scene. If present, a common eye track has implications in multiple areas including urban and industrial design, visual arts, police/criminal witness investigations and social/cultural attitudes.

Key Words:
anatomy, cinematographic, digital photography, eye-tracking, gaze-tracking, human-centred design, iterative design, mindfulness, mindful meditation, neurophysiology, psychology, self-awareness, sight, vision, visual environment, visual perception

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DEDICATION

To and For Sandra, my Wife, Life Partner and Fellow Conspirator

Thank you for your endless support.

TABLE OF CONTENTS

LIST OF FIGURES

A. INTRODUCTION

The Personal Why and How of a Photographer

I will begin with some background to try to explain, in some measure, why I am personally so interested in the multiple processes involved in human visual perception, the principles of mindfulness and mindful meditation and their relationship with the 'artist's gaze', the reasons why the so-called 'rules of visual composition' work, and why I feel that an understanding of how and why they work is, or should be, important to visual artists.

I am a visual artist and, by habit, preference and practice, a digital photographer specializing in the capture, post-capture manipulation and display of both landscape and macro images. A common theme across many beginner and more advanced courses I have taken in various artistic media are the principles or rules of visual composition such as 'the rule of nines', 'the golden ratio' and multiple others. These so-called 'rules' form the foundation of the method (at least in European and North American art) believed to produce artistic images which connect with and please both the viewer and maker. However you feel about these principles, whether pro or con, they are still taught in many beginner and more advanced visual arts courses and, like many so-called 'rules', are either followed or not by visual artists in the entirely individual creative process.

Perhaps because of a certain level of contrariness, one of the first questions I asked myself and many of my instructors in the classes I took, even while attempting to follow the ‘rules’ was; “Why?” Why or how do these principles work? Do they work for everyone? Does this mean that everyone sees things the same way? A multitude of questions revolving around visual perception followed me as I produced and displayed the images I captured.

Many viewers of my work, most particularly the macro images, had questions of their own such as “I’ve never seen that before. How do you find these things?”, which led to still another question for me, “Why don’t people seem to see what I do?” To me, the subjects captured in my macro images were in plain sight; yet many other people just did not seem to see them. Was this due to my own interest in or inclination toward visual arts or because of my training?

In an attempt to find answers to all of these deceptively simple, yet enormously complex questions, I took still more advanced and in-depth courses in photography, painting and other visual media and examined anatomical, neuro-physical and psychological studies into visual perception.

During my other explorative studies, I took a course on mindfulness and mindful meditation and began an admittedly spotty and infrequent mindful meditation practice according to the philosophical, psychological and medical principles put forth by Thích Nhất Hạnh in his 1975 book “*The Miracle of*

Mindfulness" and Jon Kabat-Zin in "*Arriving at Your Own Door*" (2008) and "*Full Catastrophe Living*" (2009). I eventually came to my own personal interpretation of the principles of mindfulness; that it is the practice of paying close and deliberate attention to your senses in and of the moment, without judgement; and attempted to fold these principles into my artistic practice. I found that there was, indeed, a change in the way in which I captured images. Instead of the 'spray and pray' method so common among tourists and beginning photographers, my photographic method became more contemplative and capturing the images I wanted required far less wear and tear on the shutter mechanism. In essence – fewer captured images gave me the same result.

My artistic and mindfulness practices, and the information gained in my research readings, led me to believe that there are three distinct, yet inextricably linked processes involved in the sense of sight; looking, seeing and perception; and that far more of the details in the visual environment were available to those who paid mindful attention to their own sense of sight while looking. I also wondered if there was a difference between visual artists and 'civilians'; do visual artists, by either innate ability or training, habitually pay more mindful attention to their sense of sight? Could I find some way to encourage what I termed 'mindful seeing' and open more of the details available in the visual dimension to others? Could mindfulness training and practice in the visual arts improve detail perception?

My studies also led me to believe that it does not matter where you come from, your ethnic ancestry, your gender, or anything else; we may *perceive* the world around us in individual ways, but we look at and see it as human beings in a remarkably similar manner. As humans, despite tremendous diversity and variations in biological equipment (rod/cone cell density, differences in colour vision, etc.) all of us who have the sense of sight share similar equipment and basically use it in a similar manner in the processes of looking and seeing, but our eyes and visual cortex are (relatively speaking) rather simple and primitive instruments. It is my belief that it is in the higher brain centres that we use the information passed to us from the eyes and visual cortex to produce individual perceptions of what we have seen. This peculiar capability, that of taking the same input and producing different results, drives the cognitively dissonant expression "You are unique … just like everybody else". In part, this study is an attempt to celebrate the similarities and diversity as well as an attempt to explore my own questions regarding visual perception.

Basic Project Description

In an attempt to explore or test possible answers to my research questions I tried to develop a method of detecting, recording and demonstrating the saccade/fixation process using gaze tracking. The project is deliberately designed to concentrate on the sensory process of seeing, rather than the more cognitive process of perception as I believe that it is in the final perception process that much of human diversity manifests.

I designed the project and accompanying study to gather digital visual gaze tracking records from multiple test subjects across the five demographic parameters below. I understand there may be multiple other variables which might affect the basic or underlying gaze track pattern, but I believe the five used are enough to begin developing the process. Later and more in-depth studies might further develop the method:

- Gender (Male, Female and Other)
  - In order to capture any possible gender-based influences on the start-point, order and content of the gaze track.
- Left or Right Handedness
  - In order to capture any possible differences in directionality of saccade movement based on the neurological differences between left and right handed people.
- First Reading Language
  - In order to capture any potential linguistically based saccade directionality influences due to reading left-to-right, right-to-left, top-to-bottom or bottom-to-top.
- Artistic History (whether or not the subject is or was a visual artist)
  - In order to explore the possible influence of artistic aptitude or training on the content and shape of the gaze track pattern.
- Age (in ten-year increments beginning at age 18)
  - In order to explore any changes in gaze track pattern that might be caused by the natural aging process or other factors.

The Research Questions

1. Is there a definable and/or demonstrable pattern in eye movements during visual data uptake that operates prior to the perception process and subsequent cultural, ideological or other analyses in subsequent or so-called 'higher' brain functions?
    1.1. If present, is the pattern common or at least similar across multiple individuals?
    1.2. If present, is there a difference in pattern between artists and non-artists?

2. Are there omissions in human visual perception caused by the natural movement of the eyes?
    2.1. How broad or comprehensive are the resulting extrapolations by the visual cortex and higher brain centres necessitated by these omissions?

3. Can a practice of non-judgmental 'mindful seeing' be demonstrated, fostered or encouraged in visual arts and other applications by using a relatively simple visual display showing the scan track resulting from eye movement that shows the viewer how much visual information has been missed because of any omissions inherent in the visual perception process?

Some Terminology Explanations

For the purposes of this project and thesis, and to avoid confusion, the terms below are briefly explained in the context of my own usages as follows:

Fixation and/or **Ocular Fixation** (from Attneave & Arnoult, "*The Quantitative Study of Shape and Pattern Perception*"):

While the eyes are never truly still (even when deliberately or consciously focussed on a single point, there is a phenomenon known as "micro-saccade") there are short periods when they are *relatively* still. These are termed as fixations.

Look or **Looking** (personal definition):

The use of the eyes as isolated from the whole of the visual perception system. This process encompasses both gross movements of the head and body and the small saccade motions of the eyes and I define it as a process that takes place prior to and separable from the system of sight or seeing.

Micro-saccade (Attneave & Arnoult):

Tiny eye movements during ocular fixations.

Mindfulness (Hạnh & Kabat-Zin and personal definition):

The conscious decision and act of paying non-judgemental and close attention to the sensations and experiences in and of the moment.

Mindful Seeing (Hạnh & Kabat-Zin and personal definition):

Paying close attention to your own sense of sight in the present moment.

Saccade (Attneave & Arnoult):

From the French for "jolt" or "jerk", saccades are the short, involuntary and very rapid movements of the eyes as they scan across a scene, image or object.

Sight or **Seeing** (personal definition):

The process that takes place in the visual cortex as isolated from the whole of the visual perception system. I define this as taking place prior to and separable from the visual perception system. It takes place *after* looking.

Vision (personal definition):

The word I use to encompass the entirety of the visual perception system.

Visual Perception (personal definition):

I define this as the process that takes place in the brain's so-called higher centres that produces what we, at levels both conscious and unconscious, accept and acknowledge as what we see. Visual perception takes place *after* looking and sight or seeing and is the final stage in vision.

Project Significance

Once the saccade/fixation process (the act of looking) passes visual data over the optic nerves to the visual cortex, and the cortex has gone through the seeing process and decided on the basic visual properties of the scene or object (shape, colour, texture, distance, motion, etc.), this data is passed along to so-called higher brain functions for further analysis in the perception process. During all three of these processes, much of the detail in any object, image or scene being viewed is discarded, dismissed, ignored or otherwise omitted from the final visual perception. In other words, we do not truly see all the details, and this results in what can best be termed as an incomplete visual perception of the world around us.

I believe that it is in these incomplete perceptions that things such as camouflage and many other optical illusions, Trompe L'oeil painting, many traffic and industrial accidents and perhaps even certain cultural or social prejudgements and prejudices make their home. If we can come to a fuller understanding of some of the limitations inherent in the visual perception system, perhaps we might be encouraged toward being more mindful, visually at least, or attentive to the world around us and the visual details it contains.

If it is possible to be more visually mindful, there are potential implications in a number of fields. Many of these fields are already using similar methods, especially user testing for advertisement and other visual media:

- The visual arts (towards methods of making 'better' or more intentionally impactful images)
- Graphic design in advertising and for user interfaces as well as web and print media (for higher user response rates)
- Urban and industrial design (towards accident and injury prevention)
- Interior and retail design (for sign and product placement)
- Medical diagnostics (such as possible cognitive screening for neurodegenerative conditions such as the multiple forms of dementia, Parkinson's and others as well as stroke/injury effects)
- Jurisprudence and legal procedure (since the testimony of eyewitnesses is not as reliable as many assume)

- Police and military visual surveillance (as vital details can be missed, overemphasized or misinterpreted)

Project Limitations

The images used as visual input in the study project may be an *over*simplification as they are restricted to digital still photography. This is a deliberate choice on my part as I am attempting to demonstrate and build a foundational dataset of saccade/fixation patterns across a variety of different scene categories or types and demographic parameters. I am also using still digital photographic images because this is my background and primary area of artistic practice and where I have the most personal experience. I have attempted to choose images which fit into eight subjectively chosen and relatively broad categories and which have what I classify as the necessary amount of visual complexity to produce interpretable gaze tracks.

Because any image displayed, still or video, is necessarily filtered through a camera lens of one fashion or another, and are therefore two-dimensional objects, this study project does not deal with depth or focus. Because there is no finer or faster auto-focus system than the one which exists in the human eye, I am assuming that fixation points in any three-dimensional scene are focused. I must also acknowledge that there is a high level of subjectivity in my choice of the actual images used in the study. This subjectivity is unavoidable as I have my own unconscious levels of prejudgement towards what is visually interesting.

My observations are extrapolated from an extremely small sampling of subjects and I was unable to study the cultural or linguistic influence of scan direction inherent in the first reading language parameter of the user survey as I did not have enough test subjects to determine this as a factor in scan pattern.

Because the saccade/fixation process is common across a vast swath of vertebrates, not just humans, I do not believe that genetic ancestry, as well as the culturally produced term “race”, would be a factor beyond the possible attendant cultural influences, and have omitted this as a parameter. The range of subjects participating in the study was an honest attempt to include as many adults with self-proclaimed normal-range vision and to consider the primary factors which I believe might influence the human saccade/fixation pattern as possible.

Because the gaze tracking equipment specializes in recording fixations, and my belief that only the detailed visual data contained in the ocular fixations is retained and passed along for further processing, I have not included peripheral vision considerations in the study. In my opinion, in persons with normal range sight capabilities, peripheral vision is primarily what we use to tell us that there is something to look at as well as serving as a stimulus for light-level ocular adjustments and to trigger saccades toward movement.

I have attempted to be as conscious as possible of my own biases as a cisgender, white European/North American male trained artist but some inherent influences are unavoidable.

B. RESEARCH DEVELOPMENT

An Explanation of My Theory of Visual Perception

As humans, when we think about it at all, we tend to assume our visual perceptions are equivalent to our visual sensory input, that we have taken in the entire scene and know what our eyes have passed on to the brain for processing. However, our visual cortex and higher brain centres assume, expand, extrapolate and sometimes outright lie. Consider, as a simplified example, the emoticon known as a "smiley face" (fig. 1):

Figure 1: A Smiley Face. (https://patagoniahealth.com/smiley-face/)

The smiley face (and most of the other emoticons involving facial expression) is really just a simple two-dimensional black-bordered yellow circle overlaid with two elliptical dots and three arcs. There is only a small, peripheral and incomplete resemblance to a human face. There is no nose, eyebrows, ears, lips, cheekbones or chin, let alone a neck or body! Despite that, and because of the cultural influences of the internet as well as the human predilection for finding and recognizing faces, your visual perception system expands and extrapolates this two-dimensional symbol into the equivalent of a three-dimensional smiling human face (or any number of other expressions depending on the alignment and shape of the various elements).

These automatic expansions, extrapolations and assumptions lead not just to optical illusions, but also to the omission and loss of a great deal of visual detail. A large part of these arguable losses is due to several factors in the psychology of visual perception (such as the human predilection toward facial recognition) but the loss of much of the missing visual data is driven by the anatomy and mode of operation of the eye itself.

The human eye has been likened to a camera in any number of stories and scientific studies, but this not completely accurate. If the eye is a camera, it's a very oddly, if not actually poorly, designed system when compared with a photographer's tool. Yes, there is a lens and an automatically setting aperture, as well as a very good auto-focus system; but compare a human retina (Gray's Anatomy, 832 – 839 and Figure 2) with its 'blind spot' (where the optic nerve joins the retina), and the macula (with its central fovea containing by far the densest array of colour and detail sensing cells) with the image sensor from a digital camera.

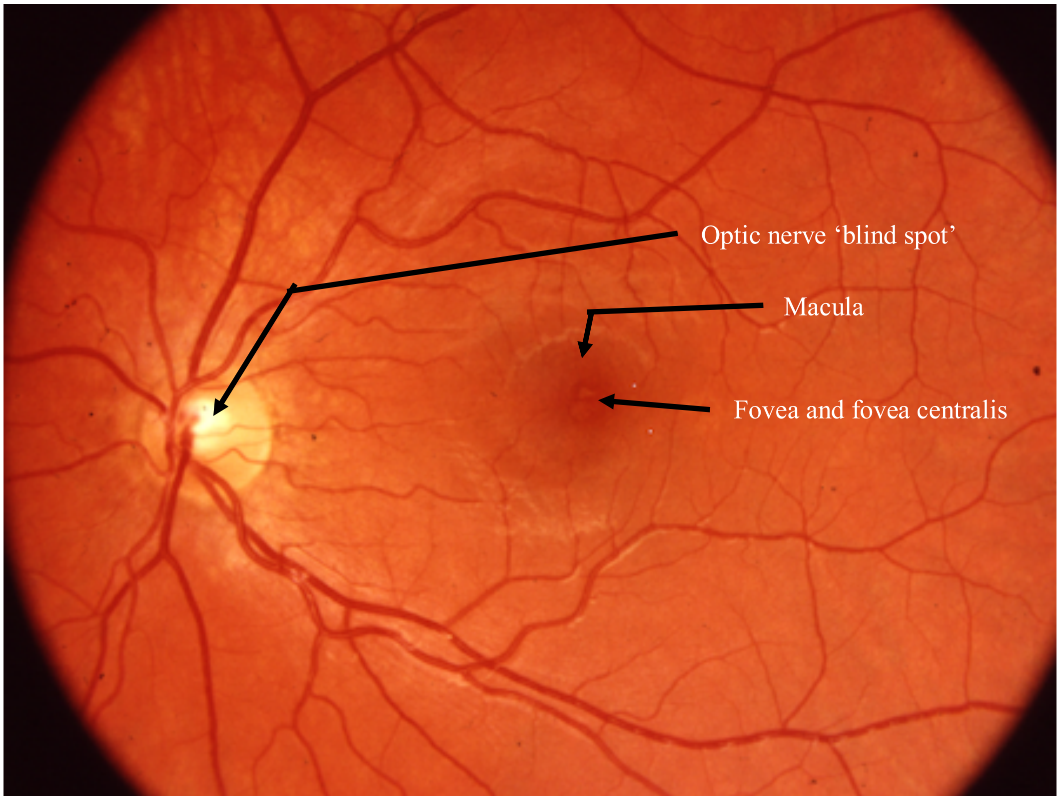

Figure 2: A Human Retina. (https://www.shutterstock.com/image-photo/medical-image-ocular-fundus-human-retina-4032055 - labelling my own)

When compared with the image sensor in a digital camera, one glaring difference immediately becomes apparent. In a digital camera's sensor, colour and detail gathering elements (pixels in digital photography terms) are organized in a deliberately calculated and arranged array and spread evenly across the entire surface, resulting in a single image such as figure 3:

Figure 3: (author's copyright): The quad of the University of Coimbra as uploaded from a digital camera's sensor.

The structure of the human retina results in a vista which is, in any single instant, markedly inferior to that which is uploaded by the digital camera, as approximated in figure 4:

Figure 4: The same scene as in Figure 3 as it might be uploaded in a single instant by the retina

Fortunately for visual acuity, the ocular portion of the visual perception system compensates for many of its own shortcomings. During the process of looking the eyes are continuously moving in a series of short, jerky motions called saccades, from the French for 'jolt' or 'jerk', (Noton & Stark, *Eye Movements and Visual Perception,* 34) and fixating and focusing on 'points of interest' (to generate a descriptive phrase). This rapid, stop-start movement results in what I equate to a series of individual 'snapshots' (as in figure 4) roughly equivalent to the frames or individual cells in a strip of movie film. I believe that the brain uses these individual frames, along with a large contribution of the detection of things to look at from peripheral vision (although this is not part of my study), to build the visual perception. According to a June 29, 2016 response from Aninda Dutta (a student at KIIT University) in the online query forum *Quora* (https://www.quora.com/What-is-the-highest-frame-rate-fps-that-can-be-recognized-by-human-perception-At-what-rate-do-we-essentially-stop-noticing-the-difference) ,

"The USAF, in testing their pilots for visual response time, used a simple test to see if the pilots could distinguish small changes in light. In their experiment a picture of an aircraft was flashed on a screen in a dark room at 1/220th of a second. Pilots were consistently able to "see" the afterimage as well as identify the aircraft. This simple and specific situation not only proves the ability to perceive 1 image within 1/220 of a second, but the ability to interpret higher FPS."

When factors such as age, fatigue, drug effects and training (such as that for fighter pilots) are factored in, the 'frame rate' of the human visual perception system varies through the range of approximately forty to two hundred and fifty frames per second. The visual cortex (a roughly walnut-sized structure in the occipital region at the back of the brain – see Gray's Anatomy, 643 - 707) coalesces these individual snap shots into what I term as sight or seeing by giving us shape, distance, motion and motion directionality, texture and (in humans and other creatures with colour sense) colour and passes this to so-called higher brain centres for further processing into our visual perception of what we see, allowing us to recognize and categorize the visual elements in a scene, as illustrated below:

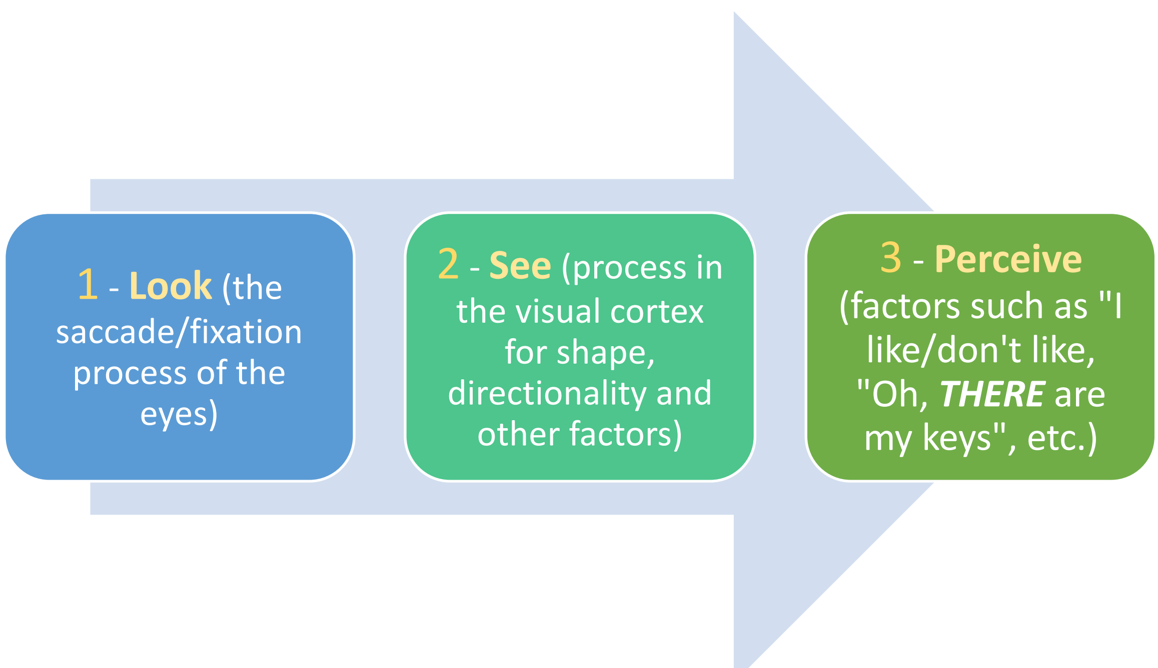

Figure 5: (Author) A flowchart of the visual perception process

This is not to say that the seeing – perceiving axis is not iterative as the full visual perception process is not a simple one-way funnel. Each sub-process involved has some feedback, as when things such as text or a logo "draw the eye". I have attempted to minimize the iterative influences of each sub-process by specifying a short 5 second scan of each image in the study. However, even a short 5 second scan still allows for some iterative influence.

Literature and Context Review

For centuries, philosophers and others have tried to define what visual perception is, how it works and how to improve its results. Aristotle defined visual perception two thousand years ago as the process of determining "what is where" (Finkel and Sajda, *Constructing Visual Perception*, 224). Unfortunately, such a relatively simplistic definition leaves much of the meat off the bones as it does not address the 'how' portion of the question.

Visual artists across multiple cultures have intuitively known and used their own definitions of the natural processes involved in human sight for at least as long or longer. For painters, in European culture specifically, I would argue that the pinnacle of this intuitive use and its integration with the scientific and artistic principles of visual perspective, shading or chiaroscuro, etc. came during the Renaissance of approximately the 14^{th} through the 17^{th} centuries (https://www.britannica.com/event/Renaissance). The Trompe L'oeil paintings and frescoes produced during this period and later, by such artists as Raphael, Correggio and their contemporaries and artistic descendants, used carefully chosen visual cues, composition, perspective and deliberate subject placement to direct the gaze of the viewer in planned patterns to influence (sometimes actually control), as much as possible, the viewer's gaze and subsequent visual perception of the works. As an example, and as Finkel and Sajda do, consider Raphael's 1509 – 1511 fresco in the Apostolic Palace "*The School of Athens*":

Figure 6: Raphael's "The School of Athens" (http://www.raphaelpaintings.org/the-school-of-athens.jsp)

In multiple interpretive articles and books, Robert Haas' "Raphael's The School of Athens: A Theorem in a Painting?" in the *Journal of Humanistic Mathematics* for example, the great philosophers depicted in the fresco, and some of the models Raphael used as representative of them, have been discussed and some have been (more or less), identified. I am not addressing the work historically or critically as this is not the function of my thesis. I am arguing my belief that the way in which the figures and groupings are placed and depicted was a deliberate and pre-planned choice by Raphael. Consider that each figure, beginning with Plato and Aristotle in the central point of the fresco's perspective, almost without exception, is depicted either gesturing, facing or both toward another. The direction of your eye's movement through the image, or gaze track, is affected by the depicted gestures, facing and placement of each subject such that your eyes are naturally drawn to the next figure.

In some cases, the artist's deliberate planning has led to years of misinterpretation or misappreciation of their works. A specific example is described in Erin J. Campbell's 1998 article in the Sixteenth Century Journal reviewing Carolyn Smyth's book "*Correggio's Frescoes in Parma Cathedral*". I have chosen to use Campbell's review, rather than the entirety of Smyth's book, because of its brevity and its summarization of most of the major details in Smyth's book. According to Smyth (through Campbell) regarding Correggio's "*Ascension*" in the dome of the cathedral, "much of the misunderstanding of the frescoes has resulted from the 'universal habit' of viewing the frescoes in the dome from the center of the crossing, looking directly up into the dome". (Page 1180). If the critic has followed the 'universal habit' cited above regarding the dome (see figure 7), they are correct when they pronounce that the perspective is poorly executed, and the depicted subjects are incorrectly placed or 'off' in many cases. In my opinion, however, Smyth and Campbell are correct in surmising that Correggio planned the work to take advantage of still another compositional principle, angle of view, and that the work was executed such that the congregation would view it in a way which allowed for their placement in the cathedral; standing in or moving through the nave toward the crossing of the dome.

This implies that Correggio's work was planned and executed to affect the congregant's gaze track from the nave, rather than vertically from below. This suggests that there is a natural, and at least somewhat controllable, gaze pattern, and that it must have been common to more or less all of the worshippers who progressed through the cathedral according to Correggio's (and the church's) plan.

I do not assert that Correggio knew about the human visual scan pattern from scientific study, but that empirical or experiential data and prior training showed him (and Raphael and his other contemporaries) that 'if I put this *here* and shape it *thus*, then I will achieve the visual effect I want'. This is one point I am attempting to make with this study; that there is a common and definable way in which all humans scan a visually complex scene or object and, perhaps, that artists and designers, at least in the European traditions, have used the information for centuries without truly quantifying *why* it works the way it does.


Figure 7: Correggio's "Ascension" in Parma Cathedral (www.agefotostock.com)

These methods of influencing gaze direction or pattern have carried forward into all the graphic arts, specifically including photography. As a contemporary example, consider the photographic work of Gregory Crewdson. I would argue that Crewdson's works are deliberately constructed to take advantage of the saccade/fixation process in human sight and subsequent visual perception.

Crewdson can be described as a photographic artist who composes his images in a cinematographic manner, where nothing in the final image is unintended. The scene and setting for the example in Figure 8, officially untitled by the artist but given the name "*Birth*" by critics and the public, was constructed to

Crewdson's specifications on a sound stage at the University of Massachusetts. As described in interviews such as the one in *The American Reader* (http://theamericanreader.com/interview-with-photographer-gregory-crewdson/) the final image was produced from hours of post-capture editing and the compositing of hundreds of separate images. All of the major, and most of the minor, individual visual elements in the image from the eerily "pooled" lighting, to the height and condition of the snowbanks, to the room key in the door and faint traces of blood on the toilet seat are carefully planned and placed in a deliberate manner.

Figure 8: Gregory Crewdson's "Untitled" (Birth) (www.artblart.com)

In my opinion there is absolutely nothing in the image that is not there by design. All the elements are placed such that the next saccade leads to the next planned fixation or point of interest. The implication is that Crewdson knows intuitively (for lack of a better term) where to place each element in the image so that the viewer's eye can find it in the order Crewdson planned or at least anticipated. If, as I believe the European Renaissance masters did and Crewdson has done in "*Birth*" and his other works, a viewer's eye-track can be anticipated, preplanned or steered, then this implies that the human process of looking or the way in which the human eye scans a scene or image is in some manner predictable, describable and capable of demonstration.

This cinematographic method of visual image production in photographic practice is described by Vincent Versace, both in the photography courses he teaches and in his 2011 book "*Welcome to Oz 2.0: A Cinematic Approach to Digital Still Photography with Photoshop*". Versace believes that any photographic image should be planned, however briefly, before the shutter is tripped to anticipate compositional factors. This attitude towards planning, in a way, almost forces a mindful attitude towards the photographer's visual sense. Versace teaches the principle to minimize what he defines as unintended visual elements (idiotic mistakes in simpler language) and terms as "artifacts". According to Versace, "artifacts are cumulative and can be multiplicative" (verbal during a course at Maine Media College, October 2008) and are to be avoided or eliminated if possible. In my own experience, a mindful use of the visual sense leads to an awareness of visual artifacts prior to shutter click and, therefore, an improvement in result.

Versace also believes that the direction a viewer's eye travels through an image, photographic or painted, can be controlled by careful; mindful in my own terminology; pre-planning and composition. He also argues (as do I) that the normal human eye moves in a predictable order when scanning a photographic image or actual scene as below:

1. Motion (though Versace acknowledges that this is not present in still photography)
2. Human figures and faces
3. Text (humans attempt, however briefly, to read any text in a scene or image whether the language is understood or not)
4. Points of high detail or focus (moving from focussed to unfocussed)
5. Points of high contrast (moving from light to dark)
6. Lines or edges

This theorizes and describes a predictable pattern in human eye movement. If this is true, then a common pattern would be detectable and demonstrable.

Historically, much of the scientific research into the process of visual perception has been focused on anatomical, physiological and neurological studies rather than artistic use and application. It is, after all, far easier to trace the biological equivalent of a wiring diagram or engineer's drawing in the attempt to understand a system than it is to discern how a soft and enormously complex clump of nerve tissue (that is, after all, what the physical brain is) takes the input from the processes of looking and seeing and uses this data in the visual perception process to solve the (entirely fictional) equation:

$$Curve\ \boldsymbol{A} + Texture\ \boldsymbol{B} \times Light\ Level\ \boldsymbol{C} \div Colour\ Value\ \boldsymbol{D} \pm Mood\ \boldsymbol{E} = your\ visual\ perception\ of\ an\ autumn\ hillside.$$

Perhaps one of the best known published anatomical studies, at least on the gross or overt visual level, is Henry Gray's famous *Gray's Anatomy*. First published in 1858, medical, surgical and art students have used this dense and lavishly illustrated text as a foundation for their study of human anatomy for more than 160 years. However, as with all purely anatomical studies, knowing the physical structure of the eye and the pathway of retina to nerve to visual cortex and the rest of the brain tells you very little about the form of the information, nor how it is organized, nor how it is processed or ultimately used to form a visual perception.

The description (on a deeper level) of the totality of the visual perception process beyond tracing the physical pathways was left to neuroanatomists and neurologists beginning with those such as Thomas Willis – who coined the term 'neurology' in 1664, and psychologists such as Freud, beginning mostly in the 20th century. A truly intricate understanding of the full visual perception process only began to be explored with the development of functional magnetic resonance imaging or fMRI (see https://psychcentral.com/lib/what-is-functional-magnetic-resonance-imaging-fmri/), reliable and precise gaze or eye-tracking systems such as the GazePoint HD Pro® system (see www.gazept.com) I have used in my study, neural network simulations and other modern biometric devices and systems in combination with psychological studies.

Early experiments lacked the equipment to discover and describe the process of how humans form visual perceptions. They were theoretical and subjective since they were based largely on what a test subject *said* they saw or perceived and not actual real-time measurable results. A subject who says "I see a teapot" is not, after all, saying much about the actual process *of* seeing the teapot, nor how 'teapot' as a visual cue is processed by the brain. Early experimenters such as the gestalt psychologists working from approximately 1912 (see https://www.britannica.com/science/Gestalt-psychology) could infer some general information about the cognitive or psychological processes involved in, or possibly some general knowledge of how a singular object outside of a full scene, was defined by a particular subject's visual perception system, but they did not have any objective way to directly measure the processes involved. They were either working on and with subjective descriptions of the cognitive or psychological aspects, or the physical and neurological systemic aspects and could not or did not relate the two in any meaningful way.

From simple direct observation it was known quite early that the eyes were in constant motion, but there were no reliable methods of recording this while simultaneously determining precisely what was being looked at until eye or gaze tracking systems were developed and became a reliable metric beginning in the late 1960's. Gaze tracking is one method that has gained great acceptance in the study of visual perception because it shows, precisely and in real time, what the test subject is actually looking at within an image or scene while his or her visual perception is being formed.

Noton and Stark's 1971 study in *Scientific American,* "Eye Movement in Visual Perception", is one of the earlier experiments using relatively modern eye-tracking systems. But this study was not, as mine is, primarily interested in the first two sub-processes of vision. Since then, gaze tracking has come into use for a huge variety of applications in graphic, website, industrial, retail and interior design as well as scientific study. This is not surprizing since the real-time accuracy of modern eye or gaze track recording systems allows for immediate adjustment in composition, colour, font and most of the other visual cues involved in design. Bergstrom, Schall and Andrew's 2014 text on the use of eye tracking, "*Eye Tracking in User Experience Design"* is an example of the spread and usefulness of the method.

Gaze tracking, as well as other methods centred on the visual perception process, are also finding uses in medical science as diagnostic tools, particularly in earlier and faster detection of various types of dementia and other neurodegenerative conditions and in stroke/injury cases. As an example, a study published in the January 2019 issue of the journal Nature, well after I began the design of my own study, by Khaligh-Razavi, Seyed-Mahdi, et al, "*Integrated Cognitive Assessment: Speed and Accuracy of Visual Processing as a Reliable Proxy to Cognitive Performance*" uses a computerized test to measure the speed and accuracy of a test subject's ability to recognize the presence of animals in digital photographs.

The peculiar dichotomy between the physical or anatomical and the psychological or cognitive appears to have been understood, or at least comprehended better, by the psychologists than by the physiologists involved. B. A. Farrell's 1977 article in volume 35 of Synthese, "*On the Psychological Explanation of Visual Perception*" is an example. Farrell directly critiques the lack of psychological and cognitive study principles in many experiments by describing a deliberately simplistic experiment in which a subject is told that a visual signal "in the form of a circular spot of light, which will then sometimes be followed at once by a bar, or thin slit, of white light on the screen, … and we will ask her to tell us at once on each trial, or occasion, whether the screen was illuminated by light or not, and, if it was, whether the bar or slit of light was horizontal or vertical." (353/II) He suggests that the experimenter has given the test subject a defined visual cue for which to search and has presupposed, without explanation or investigation, that the subject has a certain level of understanding of the concepts involved. According to Farrell, these relatively blithe assumptions discount, or omit to an unfortunate degree, the cognitive and psychological aspects involved in visual perception.

This is not to say that those studying the psychological aspects of visual perception don't make their own subjective assumptions with attendant subsequent omissions – far from it. Psychological experimenters tend to have their own biases in their studies in this area and those studies have been, in turn, refuted by other experimenters. In many ways, it takes a psychologist to catch a psychologist (to borrow a syllogism).

As an example, the famous 1999 Simmons and Chabris 'gorilla' study ("*Gorillas in Our Midst: Sustained Inattentional Blindness for Dynamic Events*.") purported to show that, during dynamic or motion intensive events, humans tend to be unable to see obvious visual data.

The study's visual scene is available on YouTube at https://www.youtube.com/watch?v=vJG698U2Mvo&feature=youtu.be and can be described as follows:

- Two teams of three people (one team in black shirts, the other in white shirts) pass two basketballs while milling around each other for approximately thirty seconds.
- The study subjects are asked to count the number of times a basketball is passed from one white-shirt team member to another during the scene.
- During approximately the fifteen to twenty second period of the sequence, a person in a gorilla suit walks into the middle of the scene, pauses to pound his chest, then walks off.

What the study concluded was that, while most of the study subjects could accurately count the number of passes (fifteen in point of fact), most of them did not notice the gorilla. The conclusion drawn by Simmons and Chabris was that humans can be blind to the obvious during visually complex motion-intensive or dynamic events.

The question asked by other psychologists in later studies was "are we really that blind to the obvious?" Teppo Felin addresses this question in his August of 2018 essay in Aeon, "*Are Humans Really Blind to the Gorilla on the Basketball Court?*" Felin makes a valid point in this article about what he terms as "the fallacy of obviousness"; that there are any number of obvious items (for lack of a better term) in any scene that we do not notice or see and that the entire notion of an obvious visual cue is extremely difficult to measure, in large part because our visual perception system is influenced both by what we are looking *at* and what we are looking *for*. According to Felin, The Simmons and Chabris study is flawed in that the test subjects are specifically directed to look for one thing and one thing only (massively reducing their ability to notice or perceive anything else). Without the direct influence of "look for the basketball passes", the gorilla becomes astoundingly obvious because the viewer is paying more attention to the entirety of the scene.

The peculiarity of obviousness and the effect of simply paying attention lead towards questions regarding the utility of what I term as 'mindful seeing'.

Mindfulness is awareness that arises through paying attention, on purpose, in the present moment, non-judgementally, according to Jon Kabat-Zin. I (influenced by the writings of Thích Nhất Hạnh and Jon Kabat-Zin) personally define mindfulness as the act or practice of paying attention, as fully as possible, to the senses and sensations in and of the moment, without judgement.

The principles of the practice of mindfulness have been studied spiritually and philosophically by Thích Nhất Hạnh (*Miracle of Mindfulness: Manual on Meditation* and other works) and physiologically and medically by Jon Kabat-Zin (*Full Catastrophe Living* and other works). Hạnh deals more with the philosophical structure and the spiritual and social good which accrues from a practice of mindful meditation. According to his studies, there is a marked increase in empathy in those who mindfully note the effect of their actions and attitudes on the world around them. On the other hand, Kabat-Zin has written extensively on the personal benefits of mindfulness and has conducted and published multiple studies demonstrating the beneficial effects of mindfulness and mindful meditation on stress, depression, immune response, inflammatory conditions and other ills. Both of these authors developed similar exercises to increase the level of mindful attention in individual practitioners.

I can only speak from a personal position on mindfulness and mindful meditation as there is, as with so many 'new age' (as defined in the West) philosophies, considerable controversy around the utility and effect of the practice. Speaking from personal experience in the practice of mindfulness and mindful meditation, and without any empirical measures, I have found that my own visual perception of any scene or object seems to include far more of the details. Along with my artistic training and practice, this has led to, again without empirical measures, an easier and more effective way of finding photographically interesting scenes and producing more deliberately impactful photographic images before any digital post-processing.

The question of obviousness has also led me to studies regarding the function and methods of the optical illusion known as camouflage. To a large degree, many among the general public would say that camouflage works because a figure "blends into the background", but this is not really an accurate description. In most cases, if there is prior knowledge or pre-warning regarding the presence of a camouflaged person, animal or object, its presence can actually be quite obvious. No matter what camouflage method is used, if a person knows or is told that the camouflaged figure or object is there, they can often readily notice it.

A thorough study of camouflage in nature, its subtypes and operational parameters is described in Tom Troscianko's 2009 essay in Philosophical Transactions, "*Camouflage and Visual Perception*". According to Troscianko et. al., much of the nature of 'hiding in plain sight' (the very function of camouflage) involves the disruption of Versace's final step in visual scanning; edge detection. If enough of a figure's edges are broken by deceptive or disruptive colouration (for example, a tiger's stripes or leopard's spots) or texture (such as the South Pacific stonefish's resemblance to a rock or an octopus' ability to change its texture) and the object remains still, then the eye will simply pass over the object without registering its presence.

According to Troscianko's study, there are at least three modes or methods of camouflage in nature which affect the detection of *moving* objects; motion signal minimization (MSM); optic flow mimicry (OFM); and motion disruption (MD). The first of these, MSM, involves simply moving slowly, and preferably perpendicular to the plane of focus, so that looming (or a slow increase in apparent size) becomes the only optical cue. OFM involves moving in such a manner that the motion is indistinguishable from the optic flow of the subject being approached. In the case of a predator, OFM involves choosing a fixed or focal point in the environment and approaching in such a fashion that any movement always lies directly between the prey and that fixed point. MD involves the manipulation of contour and form such that a misperception of motion is created, and the predator or prey look like they're moving in a direction they're not.

This thesis and project are an attempt to place my work somewhere between the eyes and the so-called higher human brain functions, between the anatomists or physiologists and the psychologists and to bring the philosophy and practice of mindfulness into this research.

In order to gain some insight into the type of design methodologies that might be required for the project, I researched several. The two which appeared to fit the ideas I was attempting to explore and demonstrate were Iterative and Human Centred design. Logical extension seemed to point strongly toward at least one of the multiple Human Centred design methodologies as I was, at base, working with the human sense of sight and attempting to integrate digital gaze tracking equipment into the study's parameters. Joseph Giacomin's article in the 2014 edition of The Design Journal, "*What is Human Centred Design?*", confirmed this. While I was not designing the test equipment from the ground up to solve a human problem, so to speak, I was at the least attempting to integrate existing digital methods into a cohesive study which used human test subjects. As Giacomin's article puts it "Human centred design has its roots in fields such as ergonomics, *computer science* and artificial intelligence." (page 2, italics mine).

Human Centred design is, by its nature, iterative as each version or iteration of the design must be evaluated by, and for, the humans for which it is being produced or for whom it is intended. Iterative Design as a methodology is intimately involved in the production of what the April of 2018 article in Enginess, "*What is Iterative Design (and why you should us it)*", calls the “digital experience”. To emphasize, I was attempting to produce an experiment to demonstrate and explain my thesis using digital gaze tracking equipment and software.

After several iterations that attempted to demonstrate a subjective example of an actual gaze track, and evaluating several different brands for utility and price, I proceeded to test my theory by using Gazepoint HD Pro® gaze tracking equipment and software, a series of digital photographic images and enough test subjects for at least suggestive data.

This project is an attempt to test the hypothesis that, by paying mindful attention to the sense of sight and the visual environment, visual artists can create more impactful images, graphic designers can create better or more usable websites and print media, urban and industrial designers can create safer environments and perhaps, just perhaps, people can begin to learn to look at each other without prejudgement.

C. PROTOTYPE DEVELOPMENT

Research Ethics Board Approval

The study's parameters and methods were reviewed and approved by OCADU's institutional Research Ethics Board as the Office of Research Services file number 101446.

Methodologies and Methods

The study project lent itself almost immediately to the principles of iterative and human centred design as the methodological bases for its creation. Since it deals with the human visual perception system, the study project had to be human centred; and human centred design is, by its nature, iterative.

At each stage or iteration in the project's development, one or more human beings were asked for their reactions into the look, feel and results of the iteration and their responses were considered and incorporated in the production of the changes for the next step.

Iterative Steps

The iterative journey to the final version of the study project is described below:

1st iteration:

- This was an extremely rough demonstration of what I mean by a saccade pattern. It was simply a quickly produced and very rough Apple Keynote® slideshow created using a 'throw-away' image I had on file which I overlaid in Adobe Photoshop® with expanded portions of the same image in what I believed to be a natural saccade pattern. The two viewers seemed to immediately understand what they were looking at but stated (and I agreed) that the nature of the overlays, and the pattern in which they were presented, were insufficiently clear. Both viewers recommended input from a greater number of people, a better image and a different format for the inserts. It was at this point that eye tracking was first suggested as a method of capturing a natural saccade pattern.

2nd iteration:

- An image of the rear of the main house at the CFC (Figure 9), was captured immediately prior to class using a Canon 5D Mk II® camera with a 50 mm lens at *f* 22 (for the greatest possible depth of field):

Figure 9: The rear of the main house at the CFC (copyright - Author)

A 50 mm lens was chosen as it closely approximates the focal length of the human eye. Nine of my fellow students and one professor were enlisted as test subjects and asked:

1. To stand where the camera had been placed.
2. To close their eyes for approximately (by subjective count) ten seconds.
3. Open their eyes and quickly state, in order, the first three things upon which they thought their gaze focused.

The information was written down to see if there was any similarity between test subjects with the results shown below in figure 10.

Viewer	Items Viewed
Viewer1	Big window - ground level, railing on balcony, chimney
Viewer2	Dark patch of roof tiles (right & above chimney), grey vent pipe (centre roof), dark patch of roof tiles closer to roof peak
Viewer3	green canopy, window beneath canopy, stone wall
Viewer4	green canopy, weeping mulberry tree, grey building name sign on terrace
Viewer5	green canopy, roof peak, trees beyond roof peak
Viewer6	flower pot central on terrace, green canopy, white pole behind flower pot
Viewer7	large window centred below awning, centre window above awning, central area of roof
Viewer8	balcony door, light above balcony door, dark roof tiles in centre
Viewer9	central potted plant on terrace, right potted plant on terrace, weeping mulberry tree
Viewer10	green canopy, rock wall (central), weeping mulberry tree

Figure 10: The viewing results

The original image was copied, and the copy was modified in Adobe Photoshop®, by vignetting, decolourizing and adding visual noise, to the version below in figure 11. The idea behind the modifications was to simulate the lack of colour and detail sensing cells across most of the surface of the retina.

Figure 11: The image from Figure 9 vignetted and decolourized

Small cropped sections or vignettes of the original image, sized to what I felt approximated the area covered by the macula and matching an amalgam of the contents of the viewer survey, were copied and pasted over this image in a manually forwarded slide show. The progression of successive slides was an attempt to show a normal saccade/fixation pattern and how the perception of the image is ‘built’ from individual saccades and fixations over time. The slide show was shown to several of my fellow OCADU students at CFC for comments and suggestions. Their comments suggested that the vignettes or cropped sections used were jarring, rather than demonstrative as they were relatively large, hard edged and rectangular and needed to be more carefully placed to match the actual position of the segments used. Once again, eye tracking was suggested as a more precise method but, as I did not, as yet, have any equipment to do this, I continued in a similar fashion for the next iteration.

3rd Iteration:

- This was similar to the 2nd iteration but used a different digital image, this time taken from my own photographic library. Small vignettes were extracted from the original using Adobe Photoshop®, with the extraction field modified to be circular and with feathered edges to better simulate the more gradual fall-off of detail and colour at the edge of the macula in the retina. The result was, again, shown to several people, including some of the staff from the CFC, for comment and suggestions. Comments included an improvement in the effect in comparison with iteration 2 but that the order and placement of the vignettes needed extreme care, or the viewer might feel ‘forced’, rather than agreeing that this was a natural gaze track over the image. One of the more interesting suggestions from CFC staff was that it might be far more effective if either an auto-rolled slide show or an animated video was used.

4th Iteration:

- The same method and image were used to produce a short video on a Mac PowerBook® using Wondershare’s Filmora®. Extra care was taken with the placement of the vignettes and this was noted by viewers as giving a smoother and more realistic simulation of a natural saccade pattern. The effect was a far clearer demonstration of the saccade/fixation process during the construction of a visual perception. However, it was noted by at least two of the viewers that there was still a great deal of ‘authorial voice’ in the presentation. They thought that it still forced the viewer to follow my subjective interpretation, rather than a natural saccade/fixation pattern. One suggestion for a reduction in authorial voice was to move back to a manual slide show with the advances triggered by the test subject. Another suggestion was to use multiple types of scene or image as humans might scan different things in different manners.

5th Iteration:

- This was the last of my 'demonstrational' prototypes as I intended, at this point, to move to gaze tracking as a method of capturing the actual and natural human saccade/fixation pattern and had begun the process of procuring a gaze tracking system. As suggested in the reactions to the 4th iteration, this was a viewer triggered slideshow progressing through what I believed would be the saccade/fixation points over four different types of image as below:
    - Architectural (a man-made structure or building)
    - A "natural" landscape
    - A human face and figure in an isolated pose or portrait setting
    - A macro photograph (close enough to the subject to make it abstract and at least momentarily difficult to identify)

  As with earlier iterations, original images from my photographic library were chosen and copied. Vignette borders were added, and the images were decolourized and had a significant portion of visual noise added (all in Adobe Photoshop®). Small circular and feathered portions of the original image were overlaid in a simulation of a normal saccade/fixation pattern in the copies – each slide adding one of the small vignettes. All the viewers stated that they agreed that it was a demonstration of a true saccade pattern but, again, recommended eye-tracking as a method due to the 'authorial voice' issue.

6th Iteration:

- Having procured a Gazepoint HD Pro® gaze-tracking system, which uses an infrared video camera and accompanying software to track and record the saccade/fixation motions of the eyes in individual subjects, I increased the number of images from four to eight in order to capture as much variety as to type or category of scene or image as possible. I had not, as yet, finalized my choices for the images as I was unsure of whether to use my own or stock images available on the internet. However, I did know that I wanted to use images which fit into eight broad categories of what could be termed 'normal' or 'everyday' scenes across:

- Architectural (a man-made structure or building)
- A "natural" landscape
- A human face and figure (female) in an isolated pose or portrait setting
- A human face and figure (male) in an isolated pose or portrait setting
    - The above two in order to see if there was a gender-triggered difference in pattern
- A human face isolated from the rest of the body
- A street or crowd scene (multiple human figures in a visually complex setting)
- A macro photograph (using a relatively recognizable subject)
- A macro photograph (close enough to the subject as to make the subject abstract or make recognition difficult)

A variety of images (both my own and stock and updated frequently as I tried to decide which images were best suited) were imported into the GazePoint® application as a slideshow with each image shown for three seconds while the infrared camera in the GazePoint® hardware tracked and recorded the eye movements of test subjects. While the subjects felt that this produced valid data, it was felt by fellow students used as iteration testers that the three second scan used in this iteration was not really enough time for a conclusive amount of gaze-track data and that some form of spacer at the beginning and between each slide was needed to isolate each particular category of image and to reset the test subject's gaze.

7th Iteration:

- This was similar to the 6th iteration, but with the images shown for five seconds and a 30% grey spacer slide with a centralized "smiley face" inserted at the beginning, between each image, and at the end of the slideshow. Similar reactions were gained from test subjects, but it was suggested that the "smiley face" created too much of a forced start point to the gaze track and should be eliminated. It was also suggested that the spacer slides did not need to be shown for an equal amount of time as the images.

8th (final) Iteration:

- The "smiley face" image was removed from all the spacer slides except for the final slide and the spacer slide's timing was adjusted to three seconds. A "Thank You" text box, along with the "smiley face" was inserted in the final slide to signal end of test. This iteration was used in the data gathering study.

D. STUDY RESULTS

Study Parameters

Volunteers with self-described normal range vision were enlisted as study subjects per the strictures set forth in REB file number 101446 and given a questionnaire (see appendix) requesting information in five demographic areas which I believe might influence their gaze track pattern or patterns:

1. Gender (Male, Female or Other)
2. Whether they were Left or Right handed
3. The language in which they first learned to read (as an attempt to capture any possible culturally or linguistically derived directionality of gaze track)
4. If they were or had ever been a practicing visual artist (to see if there is a difference in fixation amount, pattern or other. Also, to address something of mindful looking or seeing as part of the 'artist's eye')
5. Age range defined in 10-year increments beginning at age 18 (to capture possible age-related differences in fixation amount, rapidity or pattern)

Eight images, a mix of my own and one stock image from the internet, were selected and inserted into the GazePoint® system, along with the 30% grey spacers, as a slideshow. The images were shown for five seconds each with the spacers shown for three seconds each. The images chosen and the reasons for each are below as figures 12 - 19:

Figure 12: A Landscape (Copyright – Author).

A natural landscape with what I believe is sufficient visual complexity for a valid gaze track with as little visual distraction such as human figures or text as possible.

Figure 13: An architectural image (Copyright – Author).

To me, this is a visually interesting building with sufficient visual complexity for a valid gaze track. There are minimal text or graphic elements (the sign over the door and the Canadian and provincial flags) and no human figures to distract.

Figure 14: Human figure – Female (Copyright – Author)

The young female subject is in a portrait setting, and therefore visually isolated with no overt visual distractions in the background while the lace pattern in the dress provides enough visual complexity beyond the subject's facial features to trigger a valid saccade pattern.

Figure 15: Human figure – Male (Copyright – Author).

As with figure 15, the subject is isolated, although the background is more visually complex than the one in figure 15. The open shirt and Batman logo are separated enough from the facial area to provide a possible second point of interest, rather than a distraction.

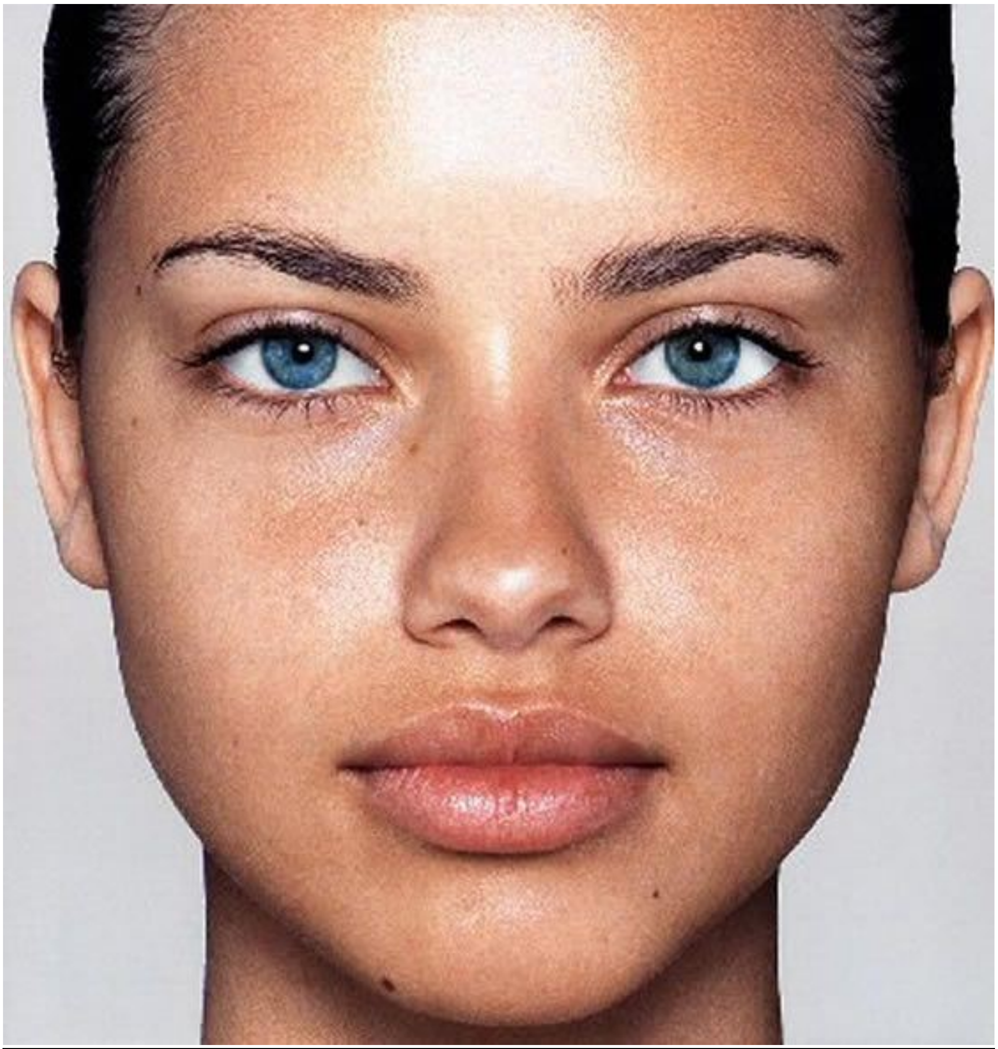

Figure 16: Human Face (www.shutterstock.com)

The face is isolated from any visual distractions such as clothing, background or the rest of the body so that a gaze track pattern would concentrate solely on facial features.

Figure 17: Crowd or Street Scene (Copyright - Author)

There is a sufficient number of human figures to qualify this as a crowd or street scene with enough visual complexity in the background to determine if this detracts from the anticipated gaze track.

Figure 18: Macro I – recognizable subject (Copyright - Author)

This was chosen as an example of a ‘brief glance at a close subject’ scene. Because of the swirling water the image has visual complexity and recognizable elements (stick and leaves) for a valid gaze track.

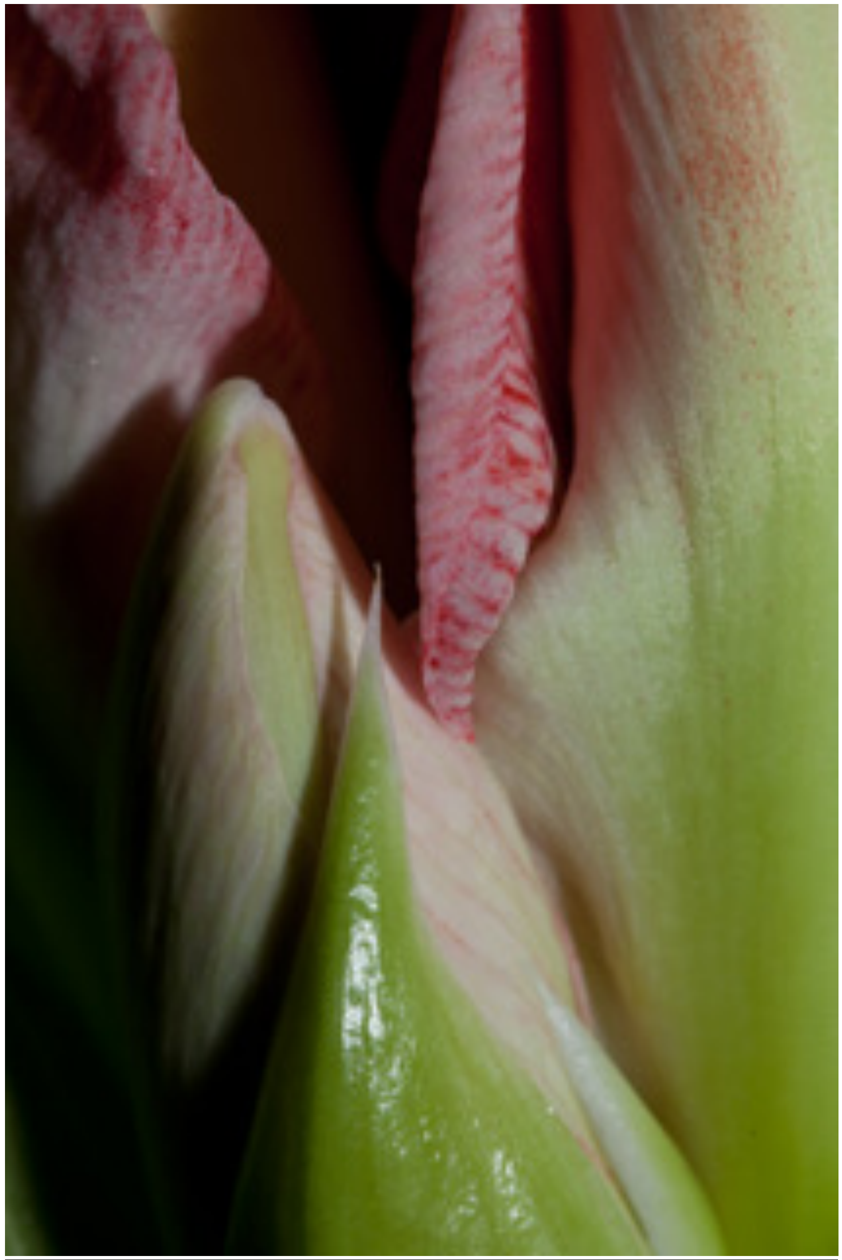

Figure 19: Macro II – Abstracted Subject (Copyright - Author)

While most viewers quickly recognize this as an opening flower (or part of one), it is abstracted enough for a valid gaze track over a briefly difficult to interpret subject.

Twenty-five volunteer test subjects participated in total, with three withdrawing and having their files deleted from the study. The following (figure 20, see also appendix) is a chart of the demographic spread in the test subjects.

Age Range	Number
18-30	3
31-40	7
41-50	1
51-60	3
61-70	7
71-80	1
Total	22

Artist?	Number
Artist	7
Non-Artist	15

Gender	Number
Male	12
Female	10
Other	0

Hand	Number
Left	4
Right	18

Figure 20: The demographic spread of test subjects

E. OBSERVATIONS & DISCUSSIONS

Reflections on Project Limitations:

- **The Limitation:** The images used as visual input in the study project may be an *over*simplification
  - **The Reflection:** There are more sophisticated gaze tracking systems available that allow for use in real-world environments and VR. If the difficulties inherent in controlling an external environment can be overcome, then further studies of this nature could be staged in real-world locations.
- **The Limitation:** There is a high level of subjectivity in my choice of the actual images used in the study.
  - **The Reflection:** This subjectivity may very well be unavoidable. I, as all people do, have my own unconscious levels of prejudgement towards what is visually interesting. However, if my hypothesis is correct, a random selection of images from an online photo bank would still produce similar results. I do not believe that the source of the images would materially matter.
- **The Limitation:** The study's conclusions are subjective and drawn from direct observation of test subject files
  - **The Reflection:** This may be solvable by recruiting someone else to either review the results or be trained in my methods to run concurrent similar studies.
- **The Limitation:** The conclusions are extrapolated from an extremely small sampling of subjects and I was unable to study the cultural influence of scan direction inherent in the first reading language

parameter of the user survey as I did not have enough test subjects to determine this as a factor in scan pattern.

  - **The Reflection:** The simplest solution is a longer study with a greater number and variety of test subjects.

- **The Limitation:** Because the saccade/fixation process is common across a vast swath of vertebrates, not just humans, the culturally produced term "race" has been omitted as a parameter.
  - **The Reflection:** From the beginning, I have maintained that "race" is a culturally derived or produced construct with null value in studies of this nature. This continues to be my contention.

The Limitation: The range of subjects participating in the study was an honest attempt to include as many adults with self-proclaimed normal-range vision as possible and to consider the primary factors which I believe might influence the human saccade/fixation pattern as possible.

  - **The Reflection:** As with the study size limitation, the simplest answer is a longer and more varied study. Further factors could be included as necessary.

- **The Limitation:** The gaze tracking equipment used in the study specializes and is largely confined to recording fixations and displaying same in varying ways.
  - **The Reflection:** As the study is deliberately designed to isolate the seeing process from the perception process, this is not (in my opinion) a true limitation.
- **The Limitation:** I believe that only the detailed visual data contained in the ocular fixations is retained and passed along for further processing and I have not included peripheral vision considerations in the study.

- **The Reflection:** I believe, and have stated elsewhere in this paper, that peripheral vision functions largely to inform the brain that there is something to look at and peripheral visual stimuli are not retained as part of the final visual perception.

- **The Limitation:** I have attempted to be as conscious as possible of my own biases
  - **The Reflection:** Some inherent influences and biases are unavoidable. Beyond being as conscious as possible of these inherent biases, and working around them as much as possible, there is no real way to avoid them.

Within the limitations stated above, all of the test subjects' fixation map, heat track and density map files were viewed both as individual files and overlaid with others in both still and dynamic or moving mode. The still or static result for each image is shown below as figures 21 – 28 with the fixation tracks from all subjects overlaid and the outlier filter set at 0.45 seconds to illustrate that there appears to be a common underlying area or pattern of fixation.

By my own observation, the shape and content of the gaze tracks, or overall pattern, appears to be specific to either the image itself or the image type or category, most markedly with the images involving human figures or faces. I believe that this appears to point to a closer influential relationship between full perception and the process of seeing than I suspected and may be an answer to my second question. It would appear that we *see* with the eyes and visual cortex and *perceive* with the higher brain centres. This would suggest that the visual perception process is an amalgam of all three stages of sight where each stage affects the others to a greater or lesser degree depending on individual subjects. A precis of the image types with all subjects' gaze tracks overlaid and my own observations regarding the gaze tracks is in the following pages:

Figure 21: Landscape overlay

In my opinion, the early fixations in the gaze tracks over the landscape image, almost universally, are concentrated on the skyline and over the central rounded hill and sunrise and along the shoreline to the right with a separate set of fixations on the small rocks protruding from the water at the bottom of the image.

Figure 22: Architecture Overlay

The fixation content and pattern for the architectural image across the participant spread appears to begin around either of the flags above the door, followed by the facing windows of the building, starting at the flags and moving through the first storey from left to right, then up a storey and right to left.

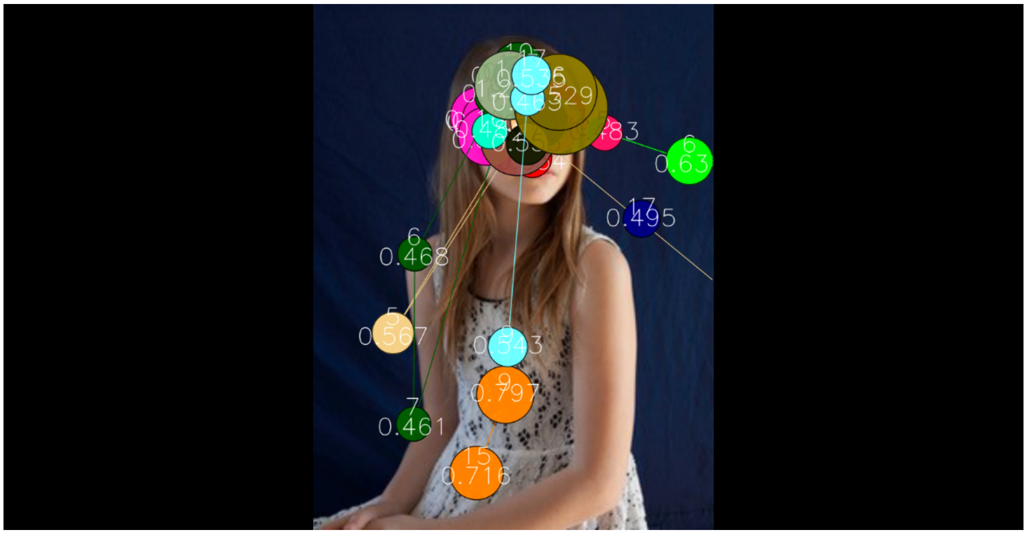

Figure 23: Female Figure

With all the subjects, the fixations in the gaze track over the female figure both begin and concentrate markedly on the facial area (most particularly the eyes) with a few short outliers around the subject's upper torso.

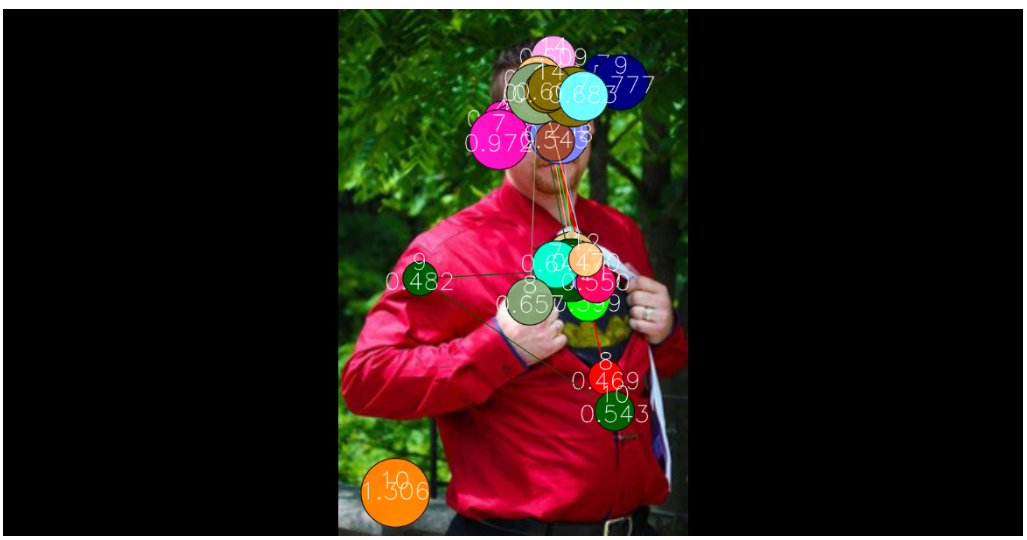

Figure 24: Male Figure

As with the female figure, the gaze track pattern over the male figure begins and concentrates on the head and face. There is a moderately dense array of fixations around the open shirt with the Batman logo (I believe this is most probably because of the strongly graphic and culturally familiar nature of the visual element).

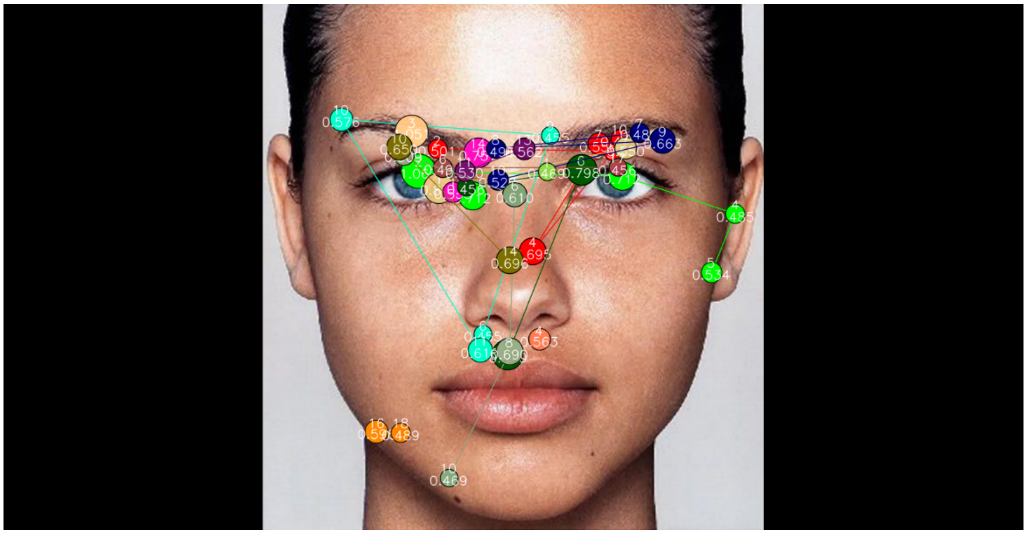

Figure 25: Human Face

In my opinion most of the gaze track pattern over the human face is a particularly striking and common inverted triangle over and around the eyes, nose and mouth of the subject. Notably, however, among the test subjects with an artistic history there are a number of what GazePoint terms as “outliers” where they appear to have noticed or attempted to gather more details (note the brief fixations on the left ear and around the dark spots or moles on the model’s chin).

Figure 26: Crowd Scene

The gaze track pattern in the crowd scene follows a common line across the heads and faces of the people in the crowd with a large number of early and longer fixations around and over the face of the girl in the centre of the image. This appears to agree with Versace’s visual ordering as to the primacy of human faces and figures in any image or scene scan.

Figure 27: Macro I

By my own observation, the most common feature of the gaze track patterns in this image is that they appear to begin with a set of fixations around the clump of leaves adhering to the stick or branch protruding from the stream. There are relatively isolated fixations on the yellow or orange leaves in the water as well as the more contrasted swirls. Versace's ordering is, again, in agreement here. The fixations are over focused or highly detailed elements, or over points of relatively high contrast.

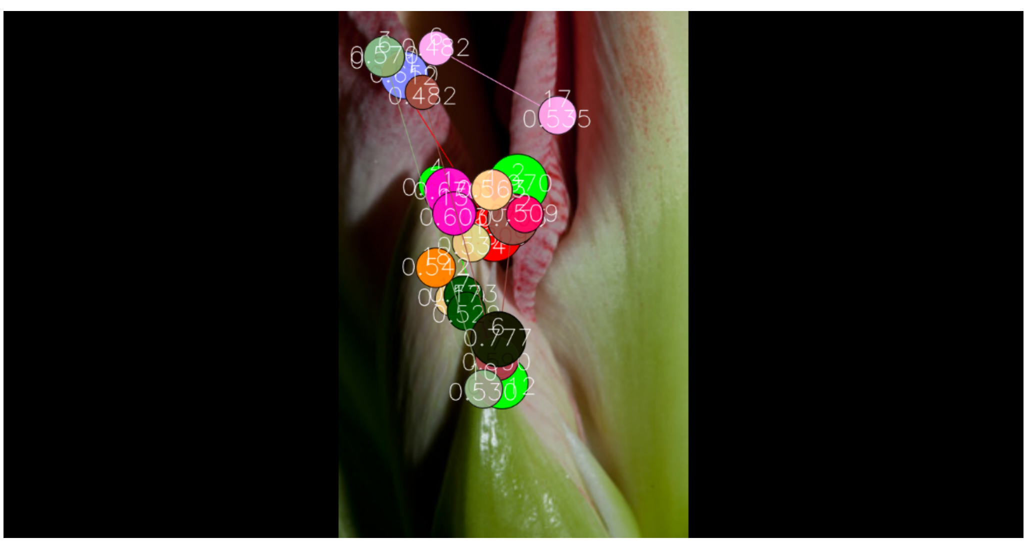

Figure 28: Macro II

The gaze track patterns of the test subjects scanning the second macro image follow an inverted triangle beginning with the bottom point centred on the bright green 'spike' in the centre of the image. As with the first macro image above, Versace's visual scan order (see pages 20-21) is followed by a significant majority of the test subjects.

The sample size of the study is admittedly small and does not contain a truly comprehensive demographic spread. This means that the study results are only suggestive, rather than conclusive. What is required, I think, for truly conclusive proof (or indeed, refutation) of my hypothesis regarding gaze track commonality is a longer and deeper study using the same method over a much more inclusive subject database. A different study using the same gaze tracking methods but geared toward the 'rules of composition' in which the images used strictly adhere to the 'rule of nines' and others might either prove or disprove their validity. Given the current study's limitations and lack of fully conclusive data, I can only state my own subjective observations as below:

1. There appears to be an underlying similar and common gaze track pattern as to the shape and content of the gaze tracks over the range of participants, varying by image type. This appears to answer the first of my research questions affirmatively. It also seems to explain, in my opinion, the compositional principle of the 'golden ratio'. If the fixation groupings in the patterns are examined in isolation from the rest of the scene, the majority of the fixation point groupings or clumps appear to fall into an area which fits within the shape defined by Euclid and his mathematical descendants. Without delving too deeply into mathematics, this is defined as the ratio: $1 : \frac{1+\sqrt{5}}{2}$ which has been defined as the Greek letter phi (ϕ, pronounced "fee") where phi is approximately 1.618. The possible explanation of this may (and I stress *<u>may</u>* as this is beyond the scope of the study) be the physical constraints imposed by the relational structure of the eyes themselves as this possibly forces a natural 'comfort zone' on the

saccade/fixation area. The patterns also appear to closely adhere to the 'rule of nines' principle of composition. This may (probably is as the majority of the study images were captured by me as a trained photographer) be due to the compositional arrangement of the visual components of the images but the existence of the adherence may also be due to the ocular 'comfort zone' imposed by the structure of the eyes. As stated previously however, randomly selected images from an online image bank made up of the work of multiple photographers (professional and non-professional) across the same broad categories would likely produce similar gaze track pattern results and remove my own personal bias towards the rules of composition and perhaps provide a more objective basis for image choice. I could also have used stock images chosen by a second, and independent, party in order to remove myself from any influence on image choice. However, either option would also inject the compositional biases of multiple other photographers but might have provided more insights.

2. The shape and content, unsurprisingly given the varying content of the images, of the gaze track patterns captured in the study appear to be specific to the image type or category. In my opinion, this is most marked with the images containing human figures or faces.
3. By subjective observation, the gaze tracks of the study subjects seem to confirm Versace's "fixational order" list (see page 20 - 21) within the saccade/fixation patterns. The grouping and order of the fixation points appear to closely follow Versace's list in all of the images I used. This may be a result of my own photographic training as Versace is one of my most influential teachers and my images might tend to follow his 'visual order', either intentionally or unintentionally, and in turn may affect the way the subject scans the image.
4. Demographic differences, based on the twenty-two test subjects captured by the study, largely do not appear to affect the content or shape of the

underlying basic gaze track pattern except in the cases of age beginning with the 41 – 50-year range and artistic practice or history. This seems to support my own theory that the first two stages in sight (looking and seeing prior to and as separate from perception) are unaffected by most of the demographic differences and that it is only in the perception stage, which takes place in the so-called higher brain centres, that cultural and other influences come into play. While I was not able to collect any data for first reading language, gender and left or right handedness did not appear to affect the scan results in any appreciable way.

Age Difference:

In test subjects beginning at the 41- 50-year mark, the gaze track pattern appears to be smaller or tighter and has fewer but longer in duration fixation points within the five second scan period when compared with younger subjects, although the underlying fixation pattern remains the same. One possible reason for this may be as simple as age related reaction slowdown. Perhaps the subject's eyes are moving more slowly due to this slowdown so that they have fewer opportunities for fixations within the 5 second image scan used in the study or they spend more time at each fixation point. Overlays of the fixation tracks for User5, a 71 – 80-year-old (magenta) and User16, an 18 – 30-year-old (pink), neither of which acknowledged any artistic history, on the Human Face image are below as illustrative specimens (Figure 29). I believe that this may hint at the possible utility of visual-based studies as diagnostic tools in age-related neuro-degenerative disorders.

This speculative result was unexpected but extremely interesting. If, as the preliminary data suggests, the scan pattern tightens due to the aging process there may be a variety of reasons. Indeed, the reason could be as simple (if that word is allowed when speaking of human sensory cognition) as older subjects producing a more 'mindful' scan track due to the greater depth of their experiential database. Further study giving more, and more comparative, data points is required to explore any possible reasons. In my opinion, however, the possibility of developing a fast, relatively inexpensive and non-invasive method which may be able to assist in early diagnosis in neurodegenerative disorders would be well worth the effort as many of these serious conditions respond better with early treatment.

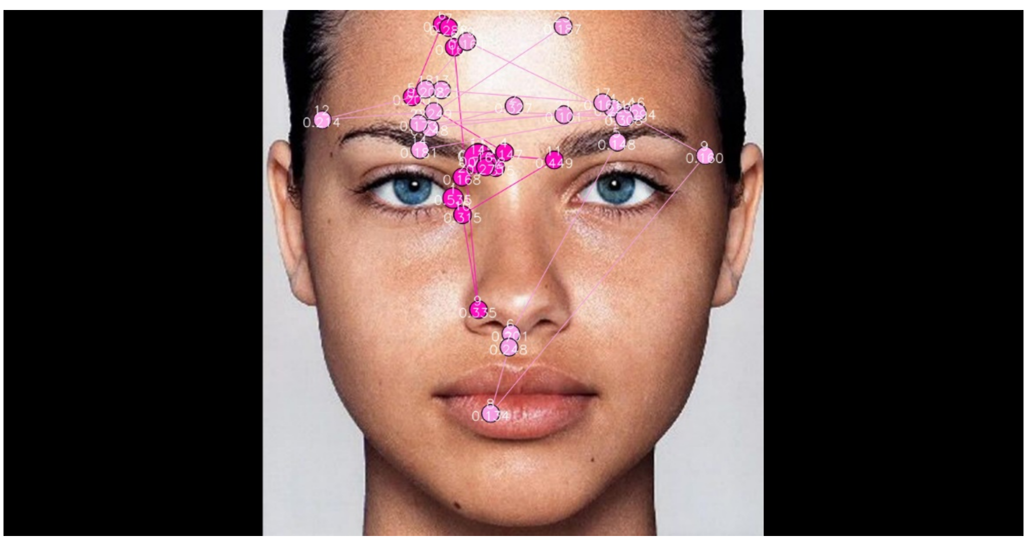

Figure 29: Age Difference Illustrated

Artistic History:

On a personal level as a visual artist, as well as for my thesis, I find the difference between artists and non-artists most interesting as I believe that it may be a function of a certain degree of what I term as mindful looking or seeing on the part of the artists (whether by training, conscious choice or inherently is beyond the study's scope). Even in older artists, where there appears to be an age-related tightening of the pattern, the gaze tracks appear to be, while containing similar content for the majority of fixations, broader and contain a greater number of fixations. The GazePoint® software allows for the elimination of what are termed "outliers" (or very short fixations) in any subject's gaze track and, if this feature is used in an artist's file, many of the fixations outside of the typical, or underlying, gaze track disappear. This suggests that artists (by training, inherent ability or both) are capable of and attempt to gain more detail out of any image. This difference fits, at least loosely, into my definition and experience of the effect of 'mindful looking' as well as speaks to the actual content of the term "the artist's eye".

While the similarities are easily detectable in all types or categories of image, both the similarities and differences between artists and non-artists and the age range were most marked and easily detected in the human figure, face and crowd scene images but were also evident enough for argument in the landscape image.

Examples using screen captures in GazePoint® of the image types and demographic differences above are below in figures 30 – 33:

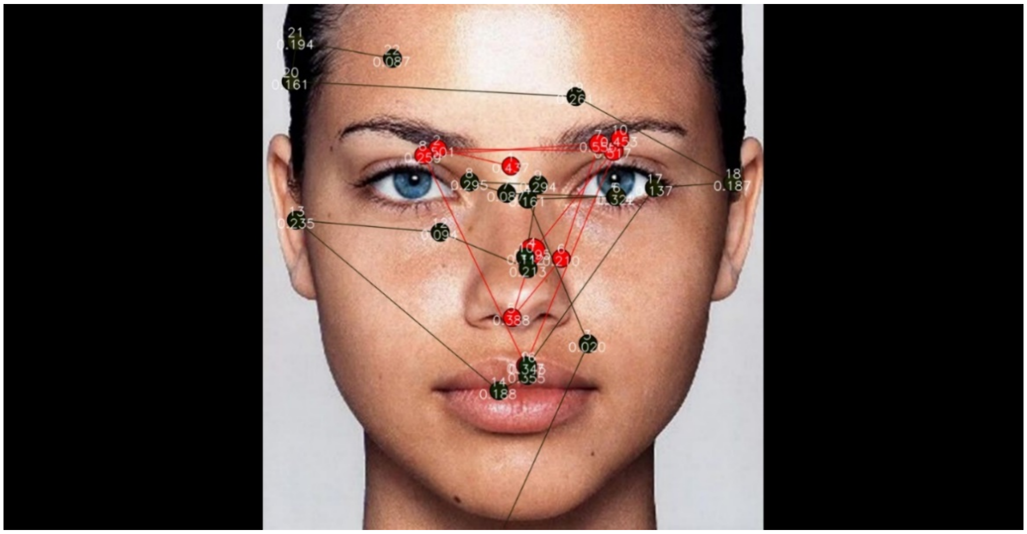

Figure 30: Fixation map over a human face

In the fixation map for User1 (a non-artist in red) overlaid with User21 (a visual artist in black) in figure 30, note the similarities in the pattern contents over the eyes, nose and mouth (a definable triangle). Note also that User21 is a visual artist generating more and a wider spread of fixations. User21 is used as the example of the visual artist in all of the following comparative examples.

Figure 31: Fixation maps over a crowd or street scene.

In the fixation map over the crowd scene, the same two subjects' (User1 in red and User21 in black), note that both participants' fixation patterns appear to concentrate on the faces (or at least heads) of the people in the scene but that User21's gaze track is, again, broader and appears to capture more detail.

Figure 32: Fixation maps over a landscape

In the landscape image, the fixation maps for User10 (a non-artist in green), overlaid with User21 (black). Note the similarities in the patterns' content and general shape. Note also, as with the human face, that User21 is a visual artist generating more and a wider spread of fixation points.

Figure 33: Fixation maps over one of the macro images.

In the fixation map for the second macro image using same two participants' files (*User10 (green), overlaid with User21 (black),* note that while both gaze tracks cover similar areas, there is far more "wandering" as both subjects may be spending more of the five second scan attempting to identify the object in the scene.

On a side note, and in a 'miracle of nature's bioengineering' vein, I found it interesting that comparatively little actual detailed visual data appears to be used in building a visual perception. To illustrate, I will use what GazePoint® calls an "Opacity Map" (which highlights the details covered by the fixations in the gaze track) and the record of a single participant (User21) viewing the second macro image. Note how little actual detail seems to be used to form the full visual perception. If we assume that the fixation points are where the macula and fovea centralis have tracked, and that only these points pass on the majority of colour and detail data for processing into a visual perception in the higher brain centres, fully two thirds of the image's details do not appear to have been scanned to any depth at all.

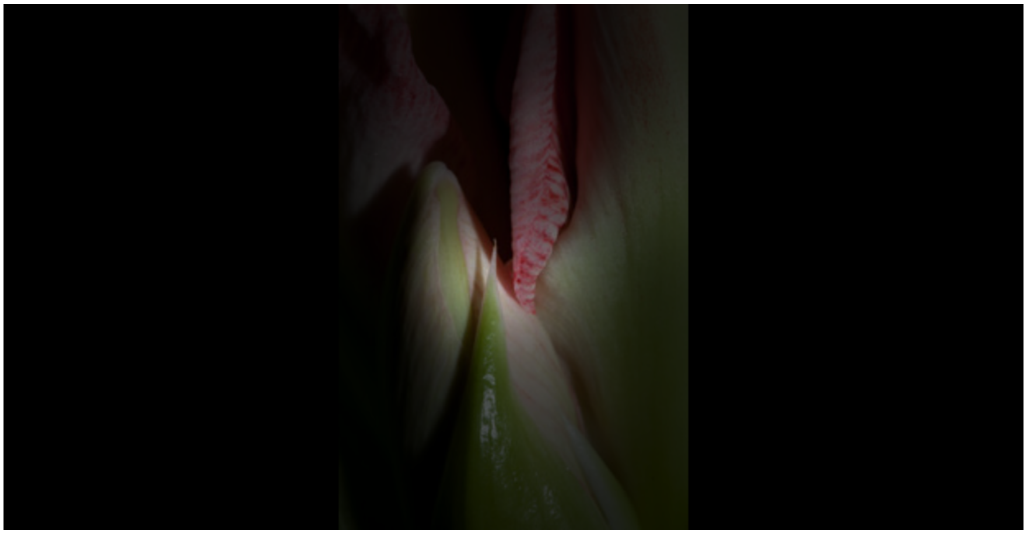

Figure 34: The opacity map of User21's gaze track

All of the scan files from the study are available as MP4 videos at:

https://drive.google.com/open?id=1OCqEth7vM2w81z0JHl0IeW-VpcJQux3e

F. FUTURE DIRECTIONS AND/OR QUESTIONS

While I believe that diversity enhances the human experience, creativity and the visual arts, for the purposes of this study I was interested in how human beings actually *see* things *prior to* any cognitive perception processes and the implications inherent in the difference(s) between seeing and perception. The study's sample size is small and gives only preliminary data, but in my opinion, it appears to at least suggest a high degree of similarity in the underlying gaze track pattern between different individuals across multiple demographic parameters and within a variety of scene types or categories. Since a common gaze track pattern appears to be present, further studies would be required to determine:

- Given the suggestive 'tightening' of the gaze track pattern in participants over the 41 – 50-year age bracket, is it possible that the use of gaze tracking might be a diagnostic tool in various types of age-related dementia or other neurodegenerative conditions as well as the assessment of stroke/injury related conditions?
    - Possibly by comparison with a database of 'typical' gaze track patterns.
        - Alternatively, by making a gaze track record part of regular physical check-ups and comparing results year-over-year.
    - In order to confirm that age-related changes *are* simply age related in normal-range adults, perhaps a simple eye examination for those test subjects at or above the 41-50-year

mark to eliminate any purely physical conditions which might not be directly related to aging.

    - Is it possible to fold this into considerations regarding artistic training for those with neurodegenerative or stroke/injury related conditions?
        - There may be a deeper relationship between art, artistic practice and the principles of neuroplasticity. If so, a regimen of visual art instruction, or at least participation, might aid in recovery or palliative care. A longitudinal study following selected test subjects over a number of years would be required to determine if this is possible.

- A longer and deeper study using the same parameters over a greater number of participants.
    - This would capture a more definitive database of gaze tracks over a wider demographic – both confirming the underlying pattern commonality and deepening the available database for further analysis and comparison.
- Possible further research into various artistic and design uses.
    - Further studies might use environments simulated in virtual reality or VR as a method of designing urban, interior, retail and industrial environments.
    - Towards a method of faster and more effective visual and/or graphic design (both commercial and artistic).
    - Towards a method of artistic image pre-planning for visual impact.
- The type of visual element which pulls fixations (in order to further confirm or refute Versace's image or scene scanning order to begin).
    - Further studies might use simplified or abstract shapes in pre-determined arrays and colours rather than visually complex

photographic or video scenes. The determinations might show which shapes, colours or arrays most effectively pull fixations in viewers.

- The study only focussed on adults with self-proclaimed normal range vision and did not examine those outside of that parameter. A further study collecting data from those who do not have similar sensing capability might give some insight into the diversity of visual perception.
- As a socio/philosophical/intellectual tool.
    - Could a regimen of mindfulness training ‘improve’ the results of artistic endeavor?
        - A longitudinal study would be required to see if the scan pattern expands or improves the amount of detail gathered in those under such training.
    - Towards a deeper understanding of how and why the visually ‘other’ is discounted or dismissed.
    - Towards pulling the population’s attention away from a constant use of screen-based experiences (getting their noses out of their cell phones) by increasing awareness of how much time it takes to experience seeing the world and its potential beauty and hazards.

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APPENDICES

Appendix A: Demographic Charts

Demographic Chart					
Subject	**Gender**	**Handed**	**Read Language**	**Artist?**	**Age Range**
User1	M	R	English	N	61-70
User3	M	R	Spanish	Y	31-40
User4	M	L	English	N	41-50
User5	M	R	English	N	71-80
User7	M	R	English	N	51-60
User8	M	R	English	N	61-70
User9	F	R	Farsi	N	61-70
User10	F	R	English	N	61-70
User11	F	R	English	Y	31-40
User12	F	R	English	N	31-40
User14	M	R	Farsi	Y	31-40
User15	F	R	English	N	61-70
User16	F	R	English	N	18-30
User17	M	R	English	Y	31-40
User18	M	L	English	N	61-70
User19	F	L	English	N	61-70
User20	M	R	English	Y	18-30
User21	F	R	English	Y	51-60
User22	M	R	English	Y	18-30
User23	F	L	Pilipino	N	51-60
User24	M	R	English	N	31-40
User25	F	R	English	N	31-40

Age Range	**Number**
18-30	3
31-40	7
41-50	1
51-60	3
61-70	7
71-80	1
Total	22

Age Range	Number		Artist?	Number
18-30	3		Artist	7
31-40	7		Non-Artist	15
41-50	1			
51-60	3			
61-70	7			
71-80	1			
Total	22			

Gender	Number		Hand	Number
Male	12		Left	4
Female	10		Right	18
Other	0			

Artist?	**Number**
Artist	7
Non-Artist	15
Total	22

Appendix B: Study Participation Documents

See also OCADU Office of Research Services file number 101446.

Participation Consent Form (abridged):

PURPOSE

This study is the project portion of my Master's thesis and is designed to:

- discover and/or demonstrate a commonality in the pattern of eye movements across multiple individuals during a five second scan of multiple photographic images
- demonstrate the level of visual detail missed during an ordinary or casual look at a scene or object
- encourage a more mindful use of the visual sense

As many participants as it is possible to gather in the time available will be studied. The plan is for up to 100 study participants, but this may not be possible.

WHAT'S INVOLVED

While anyone is welcome to run through the study, as a participant you should be:

- 18 years of age or older
- Have a reasonable level of visual acuity (glasses and/or contact lenses are not a barrier, nor is colour blindness)

As a participant, you will be asked to view a series of photographic images for five seconds each in the categories of:

- Landscape
- Architecture
- Human figure (both male and female) in a portrait-like setting
- A human face isolated from any other visual cues
- A crowd or street scene (multiple human figures)
- A macro or close-up image where the subject is difficult to recognize
- A macro or close-up image where the subject is at least marginably recognizable

Participation will take approximately ten to fifteen minutes of your time and there is no cost. No identifying data will be collected for inclusion in the study, but some demographic data is collected as follows:

- Your gender (male, female or other)
- Left or Right handedness
- The language in which you learned to read
- Whether or not you are or have been a practicing visual artist
- Age in 10-year increments beginning at 18

POTENTIAL BENEFITS

While I cannot guarantee any personal benefit to participation, you may gain some insight into the amount of visual detail you miss as you go about your daily routine. It is possible that a more mindful use of your sense of sight may be encouraged once this is demonstrated at the end of your participation.

The benefit to society is somewhat problematic as the study is also an attempt to demonstrate a commonality across multiple people. It is possible that demonstrating this commonality might remove one small barrier between people of different backgrounds.

POTENTIAL RISKS
While the potential risks are minimal, they include:

- Mild eye strain (if this occurs, the study will be paused, and you will be asked if you wish to continue)
- Some discomfort if there is any physical contact between the investigator and study subject (every effort will be made to minimize physical contact)

CONFIDENTIALITY
This consent form is the sole portion of the study documentation which contains any identifying information (your name and signature). The data collected using the study questionnaire is identified solely by an anonymous file number and the two forms will be kept in separate files in separate locations.

The data collected during this study will be stored as entries in a database on OCADU servers for a period of six months and available online only to the principle investigator (David Foster), the thesis Primary Advisor (Ian Clarke) and members of the thesis defense panel. Once the study is complete, all identifying data will be deleted and destroyed although the aggregate database will remain.

INCENTIVES FOR PARTICIPATION

- No incentives, monetary or otherwise, are offered.

VOLUNTARY PARTICIPATION
While anyone is welcome to sit through the study experiment as a demonstration, participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study.

Further, you may decide to withdraw from this study at any time, or request withdrawal of your data prior to data analysis and you may do so without any penalty or loss of benefits to which you are entitled. Your choice of whether or not to participate will not influence your future relations with OCAD University [and/or other institutions/partners of the research] or the investigators [please include names] involved in the research.

To withdraw from this study, let PI know at any point during the study or you may contact the PI by e-mail, giving the file number provided to you prior to beginning your participation, no later than June 30, 2019.

If you choose to withdraw, your file will be deleted from the study database.
PUBLICATION OF RESULTS

Results of this study will be published as a student thesis and may be further published in scholarly journals and/or presented during conferences and colloquia. In any publication, data will be presented in aggregate forms. Quotations from interviews or surveys will not be used.

Feedback about this study will be available through OCADU.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the Principal Investigator (David Foster) or the Faculty Supervisor (Professor Ian Clarke) using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University [R.E.B. file #101446].

If you have questions regarding your rights as a participant in this study please contact:
Research Ethics Board c/o Office of the Vice President, Research and Innovation
OCAD University
100 McCaul Street
Toronto, M5T1W1

AGREEMENT

I agree to participate in this study described above. I have made this decision based on the information I have read in the Information-Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

Name: ______________________________

Signature: ______________________________

Date: ______________________________

Thank you for your assistance in this project.

<u>Study Questionnaire:</u>

<u>The Angels and Devils in the Details</u>

(A demonstration and study of your visual perception process)

This is both a demonstration and study of the human visual perception process. If you choose to try the demonstration, you will be shown a series of five images while the motion of your eyes is tracked. While all persons are welcome to try the demonstration, participation in the ***study*** is entirely voluntary. Study participants are restricted to visually able (glasses and/or contact lens wearers qualify, as do those with colour blindness), adult volunteers. If, and ***only*** if, you are willing to participate in the study portion of this project, please fill out the following questionnaire prior to participating. Please note that no identifying data (name, SIN, address, etc.) is requested or required and you will remain completely anonymous.

Subject Number: ☐

Gender Male ☐ Female ☐ Other ☐

Are you **Left** ☐ or **Right** ☐ handed?

In what language did you learn to read?

☐

Are you currently, or have you ever been, a practicing visual artist?

Yes ☐ No ☐

Age Range 18 - 30 ☐

31 - 40 ☐

41 - 50 ☐

51 – 60 ☐

61 – 70 ☐

71 - 80 ☐

81 + ☐

<u>Study Withdrawal Form:</u>

Study Withdrawal Information

This is the information required to withdraw from the study "Exploring the Human Visual Perception Process in an Attempt to Foster Mindful Seeing (The Angels and Devils in the Details)". The file number below is the label for your data in the study's dataset. To withdraw from the study, simply e-mail [redacted], giving the file number, and your data will be completely removed and deleted.

File Number: ☐