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**The Role of Light Variation in the Attending to and Memorisation of Stained-Glass Windows: An
Eye-Tracking and Behavioural Study.**

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Declaration

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A handwritten signature in black ink that reads "Kate Nevin". The signature is written in a cursive, flowing style.

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Summary

Chapter One provides an overview of the relevant literature concerning attention and memory. It outlines the main theories regarding attention, and how light may influence the orienting of attention via bottom-up visual information processing mechanisms. We review how salient features present in visual stimuli may have to compete with top-down influences regarding the orienting of attention. We also discuss the relationship between attention and memory.

Chapter Two details the selection process of stained-glass window stimuli for use in later chapters.

Chapter Three investigates how light variation through stained-glass windows influences how one attends to these items and how one remembers features depicted in these windows. In this experiment, light variation is represented by patches of light in different locations in the glass of these windows. To measure the effect that these small patches of light have on the attending to and memory of stained-glass windows, images of stained-glass are manipulated using graphic design programmes to create different versions of each stained-glass window where a light patch could be located on a facial region or a background region of the composition. To measure attention, participants are asked to look at different versions of stained-glass window images and their eye movements were recorded using a Tobii eye-tracker. Humans have an evolutionary drive to focus immediately on faces when presented with new scenes. Eye distribution patterns are compared between the different versions of stained-glass windows to investigate if light patches through stained-glass windows would be able to draw attention away from facial regions depicted in these images. To measure memory, a memory test is conducted immediately after each stained-glass window was presented. Participants are provided with small segments taken from different stained-glass windows and were asked which segment had belonged to the image they had just viewed previously. To investigate how the presence of static light variation influenced memory, we compare memory performance and response times between the different stained-glass window versions in this memory test.

In Chapter Four, we conduct an online experiment to investigate how dynamic light variation influences memory for the entire window. Dynamic light variation can be defined as active light and shadow patterns that move during a viewing period of a stained-glass window. For example, a tree

gently blowing in the wind outside of a church would project a subtle shadow pattern that moves across the surface of a stained-glass window. Again, we are able to manipulate images of stained-glass windows using computer graphic programmes to create versions of stained-glass windows with dynamic light patterns. We are able to fabricate the shadow of a bird flying past the window and a cloudy day. We also replicate a firework show, a rainstorm, a tree fluttering behind the window, and a lightning storm. We also create static versions of these videos by selecting frames from each of these six dynamic variation types. During the course of the study, participants view stained-glass windows with dynamic and static light variation patterns. Participants are then presented with images of stained-glass windows with no light variation manipulations and were asked if they had been shown these stained-glass windows previously in the experiment. To investigate if dynamic light and shadow patterns advance memory for stained-glass windows in comparison to stained-glass windows with static light variation, we compare memory performance and reaction times between the two versions of these images.

In Chapter Five, we discuss our findings from the previous experiments and suggest ways that these results can be applied in a practical manner. We discuss different directions for future studies investigating the role of light variation on the cognitive processes involved when viewing stained-glass windows.

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Chapter 1: General Introduction

Stained-glass is a medium of art and architecture that has been appreciated for centuries. Despite this, there have been no empirical investigations into its effect on cognitive processes. The aim of this project is to arrive at a deeper understanding of religious arts cognitive role, and how light variation through stained glass affects these processes. The first section of this review examines the development of stained glass, from its creation to the spiritual connection between light and stained glass. Here we also discuss the various types of light fluctuations that can be observed in these windows. This chapter's second section questions how changes in light might affect how attention is paid to stained-glass windows, by reviewing different theories of visual attention and looking at how top-down effects and bottom-up saliency direct attention when viewing complex visual scenes. Finally, this chapter delves into the associations between attention and memory to suggest that any effects that light variation evoke on attention should have a modulatory effect on memory as a result.

1.1 The history of stained-glass.

It is unknown what role light plays when viewers attend to less well researched stimuli like stained-glass windows. Using the dispersion qualities of coloured, translucent glass panes, stained-glass is a unique medium. Unlike typically studied media like paintings and sculptures that reflect light, stained-glass transmits light. Stained-glass windows are created to showcase their impressive workmanship in a variety of lighting conditions over time. This exceptional property makes stained-glass an attractive medium for the investigation of light on attention and memory.

Techniques for colouring glass have evolved over the course of history. Glass was first coloured in the Middle Ages by mixing in various pot metals. The addition of copper produced intense reds and blues, cobalt oxide produced blue, manganese produced pink or purple, and iron produced yellow and green (Connelly, 2010). These were combined with liquid glass and then fired. To create intricate details such as facial features and shading in clothing, black enamel paint could be added to the surface of the glass and then fired, to fuse it to the uppermost layer of the pane (Brown et al., 1993). As techniques improved in the 13th century, yellow stain could be produced by the addition of a silver chloride stain to the surface of sheets of glass, and as a result, yellow and green colours increased in popularity during this period (Rosewell, 2012). By the 16th century, the use of coloured enamel became the more popular form of staining glass. This process involved painting colours on the surface of white glass and then fusing by firing, in a way similar to glazing pottery. This technique

reduced use of lead in these windows, giving them a painting-like appearance and allowing light to permeate through (Rosewell, 2012).

1.1.1 Stained-glass and the association of light with God.

During the early Middle Ages, windows in Romanesque style churches were small, due to the limitations of architecture at the time. However, emerging new architectural ideas were established, for example, the use of pointed arches and flying buttresses, which began to reduce the amount of weight that church walls had to bear. This permitted large, multicoloured, and intricate windows to be commissioned and these additions became an integral part of the structure of ancient churches, providing both literal and spiritual illumination for both the congregation and the building. This Gothic style of Church came into being following the rebuilding of St. Denis Cathedral of Paris in the 1140s, under the guidance of the Abbot Suger (Ramos, 2014). Abbot Suger associated light with the divine, and considered light to be the manifestation of God himself, as shown by the inscription he had commissioned on the doors of his cathedral,

“The noble work is bright but being nobly bright, the work should brighten minds, allowing them to travel through the lights to the true light, where Christ is at the door”.

The works of Suger suggest that light is the manifestation of the spiritual, as well as a bridge between the natural and the supernatural. This is echoed in the Bible, an association between light and goodness, as God created light on the first day, and separated it from darkness (Genesis 1:4). There are even allusions to God being light as shown in (1 John 1:5) ‘*God is light. In him, there is no darkness at all,*’ and to the sun that illuminates his people in the Psalm (cf. Ps 37:6; 43:3). In Gothic churches, the splendour of divine worship is complemented by the light from the windows during the commissioning of stained-glass, bringing together the human and the divine, as well as the tangible and the immaterial.

1.1.2 Light variation and stained-glass windows.

The association of light with the divine is made even more spectacular with the unique property of stained-glass in that light transmitting through it can vary. This feature of the medium sets stained-glass windows apart from other art media, the viewing of which is typically less impacted by variations in light. Small air bubbles and other small particles inside the glass can disperse the incident natural light since glass is an imperfect medium, a feature that sets this medium apart from other artworks (see Figure 1.2). Stained-glass is an art form that can be appreciated and observed over

different periods of time and under many changing circumstances in order to be fully appreciated. The glass painter and designer might take into consideration how the light changes when creating these works of art.

Light variation can occur through static light differences that involve changes in light intensity, light diffusion and light location through the stained-glass window. Orientation of the window can result in diverse levels of light intensity. Day (1909) writes, *"Suppose windows north and south of a church to be of equal merit, one's appreciation of them, at first sight, would depend upon the time of day; and the light which did most justice to the northern windows would do least to the southern, and vice versa. Experience teaches a man to make allowance; but he can only judge what he has seen; and it is only with the light coming through a window that he can see its colour or judge its effect."*

Light variation can also be caused by fixed internal or external architectural features which block light and reduce the luminance of a particular portion or portions of a window (see Figure 1.1). These external features could be walls or buildings, or natural objects like trees blocking out the sun.



Figure 1.1 Examples of light variation caused by external architectural features. External architectural features prevent sunlight from transmitting and this creates blocks of shadow in the window. a) Window captured in St. James' Church, Dublin. Windows depicted in images b) and c) are located in St. Patrick's Cathedral, Dublin. Photo from Stephen Huws.

Static light variation can be temporal. This occurs as the location of the sun in the sky changes both seasonally and diurnally. As a result, the intensity of the brightness, colour and tone of the light transmitted by the same sheet of stained-glass can vary over the course of a single day or year (see Figure 1.4). This has been anecdotally recorded by the British art critic Lewis Day (1909): *“Go to the Church of S. Alpin, at Châlons, and in the morning you will find the East windows brilliantly rich: in the early afternoon, even of a bright day, they will be lacking in transparency, dull, ineffective”*. Thanikachalam and colleagues (2016) empirically investigate this phenomenon by leaving a single pane of blue glass outside and recording its change in colour intensity at various times over a day (see Figure 1.2).

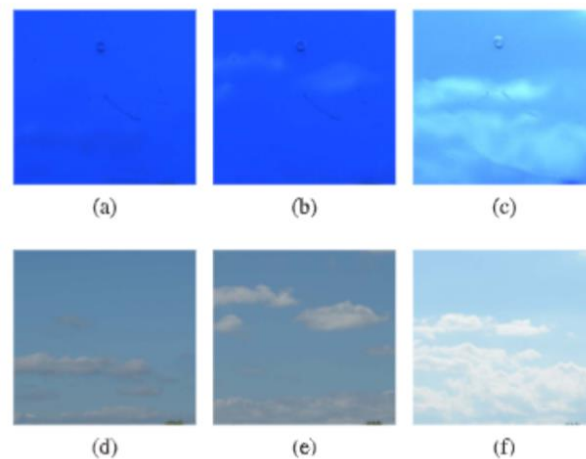


Figure 1.2 Stained-glass windows can be affected by diurnal changes in light. An identical piece of blue stained glass is depicted in (a), (b), and (c) at various times during the day, specifically at 10 am, 1 pm, and 5 pm. The respective illumination from the external environment is depicted in (d), (e), and (f). Figure from Thanikachalam et al., 2016.

In the above examples, light variation is static, as it does not vary during observation. Dynamic light variation occurs as light transmitting through glass changes during the course of viewing. While seasonal and diurnal changes in light do change over time, they usually do not occur fast enough for it to be noticed by the observer. Changes in the luminance of all or part of a window can occur by moving objects in the internal environment such as people walking in front of the window. External movement can include passing clouds, the movement of trees or leaves in the wind, or features such as birds and planes in the sky blocking out the external light.

Different light levels may make colours brilliantly illuminated, blindingly bright, or dull and weak. This plethora of different types of light variation that can occur in stained-glass windows makes it a fascinating candidate for the exploration of the distribution of attention when viewing these complex artworks.

1.2 Attention.

The human brain is constantly bombarded with visual information from the external world. In a noisy visual environment, it is critical for complex biological systems to quickly identify possible prey, predators, or partners. However, the visual sensory system (i.e., the eye) has a limited capacity for processing this information and therefore there is a requirement for a central system that will correctly identify and extract the most important parts of a visual image or scene. Humans have an active, highly dynamic ability to sample items and locations within our visual field in order to overcome our restricted visual processing capabilities.

The group of systems that limit or bias processing in different ways can be referred to as attention. Attention is the process of selecting a subsection of inputs and disregarding irrelevant inputs (Broadbent, 1958; Desimone & Duncan, 1995). A common metaphor for spatial attention is the spotlight model, which describes how attention may be directed like a beam of mental light onto relevant stimuli (Posner, 1980). Cueing experiments can be used to explore how spatial attention might function as a spotlight. In these experimental paradigms, two boxes may be represented. Attention may be cued to one of the two targets, for example, by an arrow pointing one way, indicating where attention should be deployed. This is an example of an exogenous cue. An endogenous cue may involve increasing the saliency of the object that needs to be attended to, for example, by brightening its outline. When response times are recorded, it is revealed that cues can direct attention to specific objects. A variation of this theory is the zoom lens model theory of attention (Eriksen & Yeh, 1985). This adaptation of the spotlight model of attention has an adjustable width of the spotlight beam of attention and can expand to the full area of the visual display, and then zoom into relevant regions. Sperling and Weichselgartner (1987) theorise that this spotlight can melt away and disappear, rather than the beam moving around the visual display from location to location. Further adaptations of this model include the suggestion that attention may be split across two locations (Cave & Bichot, 1999).

1.2.1 The visual search paradigm.

We can attempt to understand how visual stimuli are distinct from one another and what characteristics of a stimulus draw attention by using the visual search paradigm. In visual search tasks, participants are instructed to search for a target item amid distractor items in a visual display. This task allows us to understand how attention is oriented from one item to the next, and how our brains remember what has already been attended to. The most basic visual search tasks use artificial objects like shapes, coloured line segments, and digits (Wolfe, 1994). The number of distractors in a display is known as its set size, and search efficiency can be measured by varying the number of distractors present. To do this, response time and accuracy are recorded from participants, and a reaction time slope can be calculated as the reaction time is divided by the number of distractors present. When the slope is zero, no distractor objects in the display interfere with the detection of the target item. Smaller reaction time slopes are associated with feature search tasks, where participants are asked to find a target that differs from its distractors by one unique visual feature, such as size, orientation, or shape. A pop-out effect may be observed if the target stands out visually from its neighbours, as the method of parallel processing enables one's feature detectors to identify the target simultaneously. Conjunction search, alternatively, is a visual search method that centres on finding a target amid distractors with no distinguishing features from the target itself. Steeper slopes are generally associated with these tasks.

1.2.2 Feature integration theory (FIT) and guided search model.

The feature integration theory (FIT) is an early and influential model used to explain these differences in reaction times of feature and conjunction searchers (Treisman & Gelade, 1980). This important psychological model of human visual attention suggests that a limited set of basic features can be processed in parallel pre-attentively, but that the correct binding of these features requires attention. The binding problem of attention is the challenge of combining different features of visual stimuli together and associate to the correct, unified object. In FIT, two stages of attention are posited. The first stage, the pre-attentive stage, identifies individual features in the visual scene early on, automatically, and unconsciously. These features can include colour, shape, and size. Early vision as a result encodes these properties into individual feature maps. In the second stage of visual processing, attention is required for the binding of these features to an object. Evidence for the requirement of attention for the binding of features is revealed by the existence of illusory conjunctions (Treisman & Schmidt, 1982). Illusory conjunctions occur when features are incorrectly bound, for example, when

shown an image of a red circle and a blue square, a red square and blue circle may be remembered if attention is guided elsewhere. In Treisman & Schmidt's study (1982), illusory conjunctions occurred at a rate of 18% of trials. The incorrect binding of these features suggest that features exist independently of each other at some stage in visual processing. Attention is required to select and integrate the features present at relevant locations.

In the guided search model (Wolfe, 1994), the pre-attentive process involves both top-down and bottom-up features. In this model, items are ranked according to their attentional priority in order to create an activation map. The item with the highest priority will be the focus of a visual search, followed by the next and so on. In the guided search paradigm, a target must produce the largest activation peak in the activation map for the search to be effective. Treisman later supported the idea that top-down processes can be used to bind features (Treisman, 1986) (see Figure 1.3).



Figure 1.3 Illusory conjunctions are reduced when semantic knowledge is applied to stimuli with multiple features. In this study, participants were shown three coloured shapes with a distractor on each side. By assigning semantic information about shapes, for example, instead of seeing an orange triangle, a blue circle and black ring and instead calling them a carrot, a lake and a tire, illusory conjunctions were reduced. Image from Treisman, 1986.

In the last few decades, scientists have attempted to train computers to be able to predict where an observer would look when viewing a scene, based on the theoretical models explained above (Itti & Koch, 2001). By simulating the pre-attentive stage of visual processing, computational models of attention aim to demonstrate how the salient elements of an image influence how gaze is directed. These computational models do this by creating individual conspicuity maps for input images (luminance, colour, orientation etc.). These conspicuity maps are generated for each bottom-up feature and then these are added together linearly to create a saliency map (Engmann et al., 2009). Most deep saliency models are trained using eye-tracking information gathered from real-world scenes.

1.2.3 Bottom-up features of attention.

Factors that influence the allocation of visual attention can be roughly split into two categories: bottom-up and top-down features. These factors reflect the types of information that the visual cortex receives, information from the external world and internal signals from the internal environment, for example, prior knowledge or task demands.

William James (1890, p. 416) first characterised a type of attention that is brought on by “an instinctive stimulus, a perception which, by reason of its nature rather than its mere force, appeals to one of our normal congenital impulses”. This description matches that of bottom-up features, which are low-level features that capture attention quickly. The bottom-up deployment of attention does not depend only on sensory intensity; instead, they can be feature specific. The features that can be classed as bottom-up include, but are not limited to, colour, texture, edge, orientation, luminance, motion, and edge contrast (Wolfe & Horowitz, 2004). These visual feature dimensions are processed in the early visual system, as the signal reaches the retina, and travels to the lateral geniculate nucleus and on towards the primary visual cortex (Zhaoping, 2005). Due to this short processing pathway, stimulus-driven features capture attention quickly.

A salient object in a scene stands out relative to its neighbours due to the uniqueness of its visual feature or group of features (Krüger et al., 2016) and directs attention to its location, even if this object is task irrelevant. Saliency can be used to describe how much an object stands out from a scene it appears in. Early writers on attention discussed salience as a psychological concept (Titchener, 1908). It has been proposed that the effects of salience-driven attentional capture on orienting are quick and short-lived (Donk & Zoest, 2007). Visual search performance can be influenced by stimulus saliency (Koch & Ullman, 1985).

1.2.4 Bottom-up features of stained-glass may be influenced by light variation.

Day (1909) suggests that light variation through stained-glass can increase or decrease the viewer's aesthetic appreciation of the artwork, however, currently, there have been no empirical studies conducted investigating the effect of light variation on attention. Stained-glass windows as a medium are essentially missing from any empirical investigation in perceptual literature. Stained-glass windows are highly complex, involving many colours, shapes, figures and objects. When taking light variation into account, light can make these stimuli even more complex, as light has the potential to change the intensity and colour levels that were previously in the window. Dynamic light variation can

even add motion features to the window as light changes behind it. In this section, we briefly discuss how these physical features can alter the allocation of attention when viewing visual stimuli.

1.2.5 Light and colour as bottom-up features that have the potential to guide attention.

In his writings, James (1890) listed some examples of features he believed might attract attention. These included bright things, metallic things and moving things. Until the development of the eye tracker, the visual search task was the most often used paradigm in early studies for assessing whether the saliency of a feature was caused by endogenous or external control (Jonides & Yantis, 1988; Pashler, 1988). Variations in light intensity through a stained-glass window is likely to alter the luminance intensity of areas in the window. This change in luminance intensity is unlikely to create a stimulus that is separated into sections of white, black, and grey. Instead, changes in the intensity of light throughout the day can create more intense or weaker colours, and differences in luminance contrast. Light variation may affect the luminance value of the colours present in the panes of glass; therefore, it is important to determine how both colour and differences in the intensity value of these colours could affect the allocation of attention when viewing stained glass.

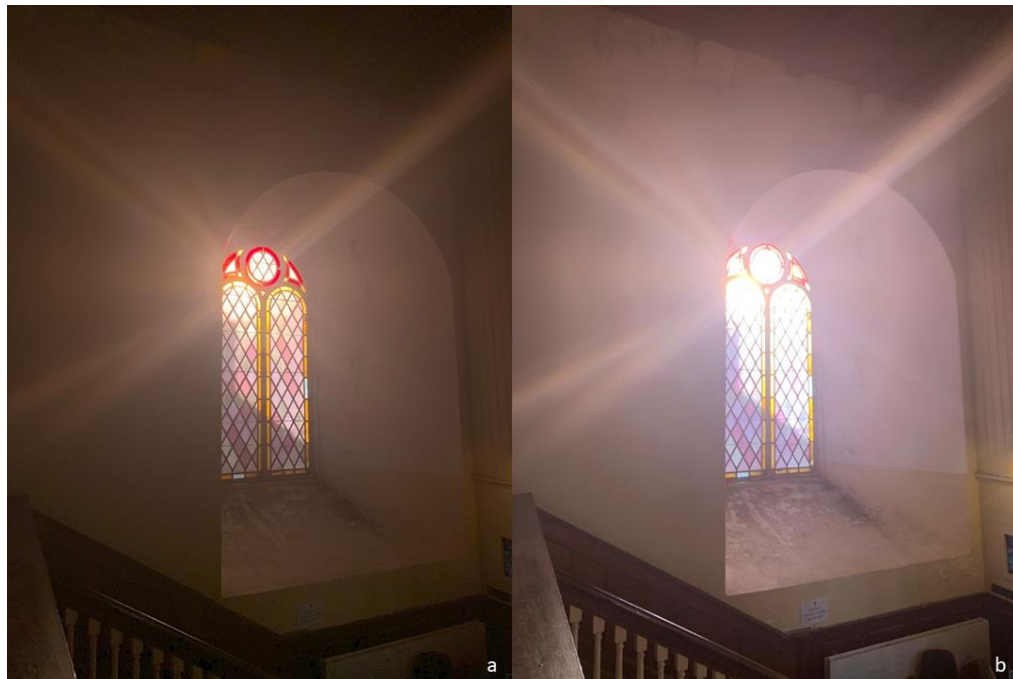


Figure 1.4 Light variation over the span of ten minutes can result in noticeable differences in light intensity, luminance contrast and colour.

In experimental studies of features that capture attention, studies focused on the perception of light measure behavioural responses to luminance. Turatto and Galfano (2001) empirically demonstrate that luminance contrast is a salient feature of bottom-up attentional control. In their experiment, six disks with a grey outline circled a fixation point against a darker background. Located in each disk were lines that were orientated either to the left or to the right. One of these lines could be vertical, and the participants were asked to indicate if this vertical line was present or absent. One of the disks throughout the experiment had a brighter grey outline than the others. This brightened outline appeared randomly throughout all trials and did not appear with the vertical line more than chance. The vertical line was found faster when it appeared in the brightened disk, despite there being no advantage to orienting attention towards this cue. When luminance values of an item differ from that of its neighbours, attention is guided towards it through bottom-up mechanisms of attentional guidance. Eye-movement studies can be used to investigate the physical properties of highly attended areas in complex scenes. Mannan and colleagues (1996) discovered that when participants are viewing grey scale images of complex scenes, the locations of the fixated areas possessed high luminance contrast. They further showed that a high value of luminance intensity was not enough to attract attention; a high *contrast* of luminance in a region is required instead to guide eye movements to that area.

Colour is another dimension that can attract attention if it differs from its surroundings. For example, attention will be guided towards a red apple in a basket of green apples on the basis of its colour contrast with its background objects. Colour has been shown to be a salient feature (Frey et al., 2008; Tatler et al., 2005). Turatto and Galfano (2000) repeated their luminance contrast saliency experiment a second time, but this time to investigate the saliency of colour. In this instance, the coloured disks were all one colour (green) but one disk in the display was red. The location of this red disk was random, and not linked to the location of the vertical line, however, when the target appeared in a red circle, response times for finding the target were faster.

Investigating how attention is distributed in works of art created by artists who use the 'chiaroscuro' method may be a useful way to investigate how brightness contrast and colour affects saliency. Strong lighting contrast is used in the chiaroscuro technique to emphasise people and objects in paintings. Famous painters like Rembrandt and Caravaggio were known for using chiaroscuro to highlight certain regions of interest in their works of art. One of Rembrandt's most famous paintings, *The Night Watch*, has the background, unimportant figures and objects painted in a dark colour, while figures in the foreground of the painting are illuminated and appear to 'pop-out.' Winter and

colleagues (2022) investigated the distribution of viewers' attention when looking at this painting in a museum. The analysis of eye movements revealed that faces and brightness attracted attention. Participants were asked to talk aloud about what they were looking at while freely viewing the painting, and the frequency of the themes of the words spoken were ranked per participant. Lighting was shown to be consciously attractive, and this was demonstrated as it was the sixth most talked about subject, following terms regarding faces, clothing, and appreciation of the artwork. Darkness and contrast were the twelfth and thirteenth most mentioned items on the list, respectively. Heatmaps of the gaze patterns of the viewers revealed that bright and textured regions in the painting captured attention.

Fontoura and colleagues (2021) demonstrated that lightness and colour in paintings capture attention in an eye-tracking study of participants viewing the *Resurrection*, a panel of a painted polyptych created by Grunewald (1512-1516). Each colour present in the painting was defined by its own area of interest (AOI). The AOIs that received the first fixations upon viewing involved warm colours such as red, yellows and brown. Yellows and browns were associated with longer dwell times and were revisited more frequently in comparison to the other colours in the paintings. Yellow was overall the most salient colour in the artwork, established as the colour that had attracted the highest number of saccades during viewing. Grunewald, like Rembrandt, uses the contrast between light and shadows to his advantage, similar to the chiaroscuro technique. Yellow is used in the painting's lightest sections, which also happened to be the colour of other salient features, including Jesus' hands and face. Together, these three elements appear to combine to create regions of very high saliency in this artwork.

1.2.6 Motion and attention.

In examples of dynamic light variation, light and shadows move across a stained-glass window. In the case of a tree being blown side to side, or just leaves fluttering in the wind, different types of motion of shadows and light may be observed. In this section, we will briefly discuss whether attention is captured by motion. Abrams & Christ (2003) argue that visual motion by itself isn't salient, but instead the sudden onset of motion is what attracts attention. In this experiment, participants searched for target letters in displays that included targets and distractors. While there was no advantage for moving letters over static ones, motion-onset items were attended to. This abruptness of change of motion may however have been salient in its 'jerky' motion (Sunny & Mühlenen, 2011). Moreover, in a continuous tracking task, unexpected changes in the direction of motion were shown

to attract attention (Howard & Holcombe, 2010). In this study, participants were asked to remember the orientation of a grate stimulus after the target had disappeared. Grates moved across the display, but motion was an irrelevant feature that did not aid the task. Performance was shown to be reduced when targets hit an invisible barrier before the task was completed. This abrupt change in motion seems to draw attention to the object and disrupt the maintenance of its orientation in working memory. Natural motion onset has recently been shown to capture attention (Smith & Abrams, 2018).

1.2.7 Top-down features of attention.

Based on array, scene, and painting studies, it is plausible to hypothesise that fluctuations of light transmission through stained-glass windows could direct attention to areas with high brightness and colour contrast, and abrupt motion onset. However, this bottom-up type of control may have to compete with top-down mechanisms of attention. This type of attention refers to the voluntary allocation of attention to certain features, objects, or regions in space. Examples of top-down attention include memory (Santangelo et al., 2015), expectations (Itti & Baldi, 2009), and meaningful images such as faces (Yarbus, 1967), figures (Buswell, 1935), text and shape (Wolfe & Horowitz, 2004). Top-down attention employs the goals and desires of the viewer and requires the allocation of focused attention.

1.2.8. Text in stained glass windows.

Stained-glass has a distinctive compositional style that may not have been examined in prior research about the distribution of attention in other media. High-level features, for example figures and text, which are not commonly present in natural scenes or paintings may override possible guidance of attention to areas with high luminance contrast or intensity in stained glass windows. For example, many stained-glass windows contain text which is not commonly present in other images of scenes and paintings. Examples of text may be located at the bottom of the window or on scrolls that the figures in the image are carrying. Text is a high-level visual feature, which can influence gaze movements (Shahab et al., 2012). This effect may be due to text providing semantic knowledge to the viewer about context and content in images and paintings (Cerf et al., 2009; Ganczarek et al., 2022; Kapoula et al., 2008).



Figure 1.5 Text is a common component in stained-glass windows. Eye movements may be focused to regions that contain words when viewing these stimuli.

An example of stained-glass windows containing informative text is shown in Figure 1.5. At the bottom of Figure 1.5a, a description of the scene can be found that says 'The baptism of our lord by Saint John the Baptist.' Below this inscription, further text states 'In memory of the parents of Edward and Elizabeth Malone RIP.' In Figure 1.5b each panel of this window contains a small banner that states the name of the person depicted. In the centre of this panel, the word 'Moses' is placed on top of a depiction of a man praying near sheep. This written text may give contextual clues to the observer about the content depicted in the stained-glass window which could potentially orient attention to regions that might not have been oriented to if the text had not been present.

1.2.9 Faces and figures are salient features of visual images, and prominent features of stained-glass windows.

One of the most prominent features of stained-glass windows is the people that they depict. One role of stained-glass windows during the Middle Ages was to visually illustrate significant stories from the Bible and to act as a teaching aid to those who were illiterate (Rosewell, 2012). As a result, Christian stained-glass windows almost always include figures and faces as they portray religious figures from biblical tales. Different churches were often dedicated to and named after a single saint, for example St. Teresa's church or St. Patrick's Cathedral, Dublin, and churches with these saintly affiliations often have windows depicting the different stories in which the saints that they are connected with appear.

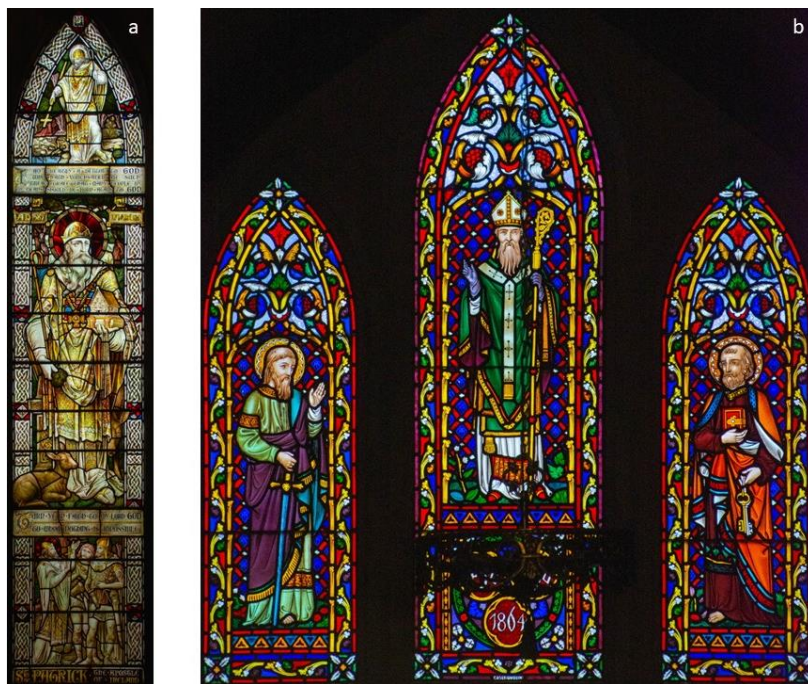


Figure 1.6 Churches named after saints often have stained-glass windows dedicated to illustrating the life of that saint. The stained-glass windows above were captured in Saint Patrick's Cathedral, Dublin, and contain representations of Saint Patrick.

Figures have been noted to be conspicuous objects in settings and paintings from early studies of eye-tracking (Buswell, 1935; Yarbus, 1967). This preferential bias of attention towards faces and figures has been further demonstrated through modern scene exploration and painting studies

(Theeuwes & Stigchel, 2006). Given that images of people are socially significant stimuli, this finding makes evolutionary sense. Due to the attention-grabbing nature of faces, some studies investigating the statistical properties of scenes and paintings that capture attention purposely exclude images with figures or faces (Fuchs et al., 2011).

It would be interesting to see if there is a relationship between light, colour, and figure saliency. In the Winter (et al 2022) study, regions of the painting in *The Night Watch* that contain figures such as the leading men and the little girl received a high proportion of fixations. It is important to note that the high contrast of these illuminated figures against the dark background may have also contributed to this observation. In stained glass windows, the faces and hands of figures are normally made from sheets of light-coloured glass. This glass can be white glass with a stain applied, following which black pigment can be used to define intricate features. In the future, further studies may investigate the relationship that facial features have on the allocation of attention in stained-glass windows.

1.2.10 The potential influence of religiosity on the distribution of attention when viewing stained-glass windows.

Some stained-glass windows do not depict religious content but are used for decorative purposes. Some contain patterns of light and colour that depict content of a non-religious nature, for example the stained-glass windows present in Bewley's, Dublin, or of abstract patterns of colour and light. However, it may be important to keep in mind the potential effect religiosity may have on the distribution of attention of the viewer when looking at stained glass.

Humphrey and colleagues (2009) observed that specialist knowledge about a certain subject was associated with a reduced influence of low-level features on attentional allocation when viewing photographs of real-world scenes, in comparison to those who were naïve to the specialist domain. This influence of top-down control mechanisms could possibly be replicated in those with high levels of religiosity compared to those who are not religious. Experts in art compared to novices are likely to have fewer fixations driven by bottom-up features of saliency (Koide et al., 2015).

Little is known about how religiosity affects any cognitive process, mainly because the demographic information that participants are asked to provide when doing experiments does not usually include religious affiliations and their levels of religiosity. Two studies can be seen to be exceptions to this theory, and they have investigated the associations between religion-related words and their orienting affect in attentional studies. Chasteen (2010) and Meier (2022) found that

associations between words relating to God or to the Devil can cue attention to targets high and low, respectively, on the vertical plane. Associations between the abstract concept of God and the physical property of light was also investigated by Meier and colleagues (2022) who found that participants were faster to respond to God-related words when they appeared in a white font on a black background, showing a semantic association between luminance intensity and contrast and the abstract concept of the divine. Meier and colleagues (2022) found that religiosity was not a factor that moderated these results.

1.3 The role of attention and memory.

How is the recall of details from stained-glass windows impacted by changes in light? According to the conclusions drawn in the previous sections, attention should be directed to various features in stained-glass via both top-down and bottom-up attentional processes. Here we will review the literature to discuss that the cognitive processes of memory and attention have a reciprocal impact on one another. If memory and attention do have a bi-directional influence on each other, then one might be able to infer that the influence of light variation on the deployment of attention, should therefore as a result, also impact the encoding and retrieval of memory of features depicted in stained-glass windows.

According to Cowen (1995), memory and attention cannot be considered separately. It has been established that memory and attention are intimately related (Chun & Johnson, 2011; Chun & Turk-Browne, 2007; Logan, 2002). Working memory serves as a short-term repository of information that may be instantly relevant and attention allows goals and behaviour to be adapted instantly by working with working memory. Long-term memory, however, can also direct attention and be directed by it (Hutchinson & Turk-Browne, 2012). Because of this, attention is able to influence what may be encoded into episodic memory, which again, can determine what memories are retrieved in the future. We consistently come across similar objects and scenes every day, and past knowledge may be useful in directing us to information that has been relevant in the past or to novel environmental features. Memory, therefore, may act as a top-down influence on the deployment of attention in the case of viewing stained-glass windows.

1.3.1 Models of memory.

Since memory encompasses a wide range of phenomena, it has the potential to have numerous effects on attention. According to the Atkinson and Shiffrin model of memory (Atkinson &

Shiffrin, 1968), there are three main modes of human memory, and each mode has a unique control mechanism. The sensory register, short-term store, and long-term store are among these three memory types. Later, this model began to be categorised further, as reflected in the multi-store model of memory. The multi-store model explains how memory functions. It speculates that the three independent components of the memory process all operate in a linear fashion. The multiple memory systems (MMS) theory can be used to classify different types of memory, components of which might guide attention. Memory, according to MMS, can be roughly classified into explicit and implicit categories (Squire, 1982; Squire & Zola-Morgan, 1988). These are also referred to as explicit and implicit memory types, respectively. The phrase "explicit memory" refers to memory that is voluntarily accessible, and it comprises working memory and episodic memory. It also includes semantic memory, which concerns factual knowledge, and episodic memory, which encodes memory for previous experiences (Tulving, 1972). Skills and habit acquisition, perceptual learning, associative learning, and priming are all examples of implicit memory.

1.3.2 Working memory.

Attention can be focused on the external world, as was illustrated in the previous sections of this review. However, our internal states can also receive attention, and this attention can be maintained even without external stimulation (Chun et al., 2011). This process of internal attention is analogous to that of working memory, which temporarily maintains a small set of representations of absent stimuli in mind for the immediate use in cognitive tasks. Working memory was first alluded to by John Locke, when he made a distinction between memory - the capacity to bring a concept back to mind after it has vanished from consciousness - and contemplation in 1690 (Logie et al., 1996). Miller, Galanter, and Pribram (1960) first used the word working memory while attempting to use computers to simulate psychological processes. Atkinson and Shiffrin used this term in a seminal publication in 1968 to describe their short-term store, and Baddeley and Hitch used it as the name of a component in the multicomponent model of memory (Baddeley & Hitch, 1974). In this model, working memory is separated functionally from long-term memory (Baddeley, 1998). The central executive, the phonological loop (for rehearsing auditory information), and the visuospatial sketchpad (for holding and manipulating images in mind) were the three components in this concept that were described as constituting working memory. In this theory, it is postulated that the central executive is responsible for the directing of attention to relevant information in the external environment. Later modulation of the multicomponent model of working memory involved the addition of fourth

component, the episodic buffer (Baddeley, 2000). This is a restricted storage system that combines information from various components to produce what is referred to as a single 'episode'.

William James (1890) suggested that the deployment of attention makes it possible to select which information is perceived and stored in a more stable form of secondary memory. Like attention, working memory is a cognitive process that appears to have limited capacity (Cowan, 2005). In 1956, George Milner proposed that short term memory had a limited capacity of seven elements, plus or minus two. These elements, referred to as 'chunks,' are defined as a basic memory unit that consists of several components that are strongly associated with one another. Cowen (1999) suggests that limits in working memory capacity are a consequence of the limitations of attentional selection.

1.3.3 The bi-directional behavioural influences of attention and working memory.

Attention and memory may share cognitive resources. Perceptual attention and reflective attention are two categories of attention described by Chun and colleagues (2011). They suggest that top-down and bottom-up attentional stimuli are included in perceptual attention. Internal mental representations initiate reflective attention. Reflective attention may be required to keep representations alive in working memory, especially in the visuospatial sketchpad. The visuospatial sketchpad is also referred to as visual short-term working memory and visuo-spatial working memory in the literature (Hollingworth, 2004). Visuospatial working memory is further thought to consist of two types of memory processes, visual working memory and spatial working memory. While spatial working memory maintains an active representation for the locations of relevant items, visual working memory maintains an active representation of the visual appearance of relevant objects (Awh et al., 1998; Stigchel & Hollingworth, 2018).

Attention has been shown to be necessary to keep representations active in working memory. This has been shown by experiments investigating the effect of divided attention on the maintenance of information in visual working memory. Smyth and Scholey (1994) asked participants to remember a set of spatial targets presented in order, and to keep this information in their working memory, as they would be asked to recall these spatial memory span items after an interval. During this interval, participants were asked to perform other tasks, for example, touching presented items, or repeating heard words back to the researcher. The spatial tasks, despite not requiring any memory load, during the interval resulted in a reduction in performance in the recall task. Awh et al 1998 further investigated the role of attention on memory accuracy. In this study, participants underwent a spatial working memory test with a choice task in the interval period. Working memory accuracy decreased

when attention was diverted away from a location that needed to be remembered. The attending to of objects in visuospatial working memory can even be measured using physiological measures. In a study conducted in 2019, participants were asked to remember the orientation of two grates, each grate being a different brightness. When participants were asked to think of the orientation of a particular grate, pupil dilation responses reflected the brightness of the grate being attended to in working memory (Zokaei et al., 2019).

Working memory can also act as a top-down attentional control mechanism. Working memory has been demonstrated to orient attention, as indicated by Awh and colleagues in 1998. Participants in this study were presented with a visual stimulus and instructed to retain this item in their working memory after it vanished. Response times were slower when participants were asked to react to a new visual target if it was located in the same region as the stimulus that was being maintained in working memory. This was also observed when the search target's features matched those of an item in working memory (Downing, 2000).

Interactions between visual working memory and attention can be used to impose top-down control of the oculomotor system. Van der Stigchel and Hollingworth contend that during the entire orienting process, visual working memory and oculomotor systems are functionally linked (Stigchel & Hollingworth, 2018). They state that the choosing of a target, keeping track of visual details during a saccade, and computing object correlation after the saccade, are all stages of this orienting process. The biasing of working memory on eye movements is significant because this implicates that memory can be a top-down mechanism in the control of attention. The burden that performing a saccade places on the visual working memory system was examined by Schut and colleagues (2017). The cost of a saccade, according to the results, was comparable to adding one more item to visual working memory. Perceptual properties of an object are activated in visual working memory, which subsequently biases attention toward visual items sharing those features. This is illustrated in the example of when distractors in a visual search task match items maintained in visual working memory, as they attract more eye movements (Olivers et al., 2006). Working memory cues from the top-down can have an early, unconscious impact on visual selection for targets that are often challenging to distinguish (Soto et al., 2008). In this study, participants were asked to maintain a prime in mind. This prime was shown at the start of each trial and could either contain the search target or a distractor that would be present in the next search array. Despite targets and distractors being highly discriminable, the prime in working memory had an influence on the first saccade's orientation and

response latencies. Even when there are salient bottom-up cues present, top-down search guided by memory could alter selection.

1.3.4 Attention and long-term memory.

The previous sections have demonstrated how working memory and attention interact with one another in bi-directional manner, however, is this also the case for long term memory? It stands to reason that focusing attention should increase chances for successful recall for longer retention periods. Uncapher and colleagues (2011) argue this point and suggest that both top-down and bottom-up focus have distinct influences on the perceptual regions associated with encoding visual information within episodic memory stores.

1.3.5 How does semantic knowledge of a scene influence the guidance of attention?

Facts regarding our reality are included in semantic knowledge, which is our broad understanding of the world. It has been demonstrated that semantic knowledge and episodic long-term memory play a part in the direction of search (Võ & Wolfe, 2015). Semantic understanding of a visual scene may provide the viewer with context for what they are seeing. This context may be referred to as the scene's gist, the broad visual category that can typically be summarised in a few words (Sampanes et al., 2008). An example of using semantic knowledge to guide eye movements would be the migration of your eyes to the sink when asked to find a tap in a kitchen scene.

The first empirical study into the effect of semantic knowledge on the viewing of scenes was conducted by Loftus and Mackworth (1978a). In this study, participants were shown images with objects that were either semantically consistent or inconsistent with the surrounding scene. For example, a farm scene would contain either a cow or an octopus. Participants were asked to study the scene for a later recognition test. Loftus and Mackworth discovered that during scene watching, viewers tended to focus on the inconsistent items earlier than the consistent objects. Most dramatically, following the initial fixation on the scene, viewers were more likely to shift their focus to a semantically contradictory item than a consistent one.

A similar study has been conducted by Henderson and Hollingworth (1999) to show that semantic knowledge can affect the distribution of eye movements when viewing line drawings of complex scenes. They observed that semantically inconsistent objects do not occupy the first few saccades when presented with scene stimuli. However, they did find that fixation densities and fixation durations were affected by semantic consistency. Experiments using scrambled scenes

further demonstrate the significance of semantic information by demonstrating that our attention is drawn to places where an object would be expected to be given the scene's context. Võ and Wolfe (2013) asked participants to take part in visual search tasks involving scenes with objects rearranged to be in improbable backgrounds or by removing the scene background entirely. These object and scene inconsistencies resulted in longer response times and greater coverage of the visual display. Contextual guidance based on the scene schema interferes with search in this situation.

Based on these results, semantic knowledge may be a form of memory that can act as a top-down control mechanism on the deployment of attention. It is interesting to contemplate what effect semantic knowledge might have on the guidance of attention and eye movements when one views religious stained-glass. For example, could knowledge about Saint Anne influence how one attends to a stained-glass window containing a depiction of this saint? Saint Anne is known to be Christ's grandmother, and Mary's mother. In stained-glass windows she is often depicted teaching a young girl how to read (Rosewell, 2012). It is interesting to contemplate how eye movement patterns and fixation durations may differ between those who are familiar with this character, and those who have a low level of religious knowledge.

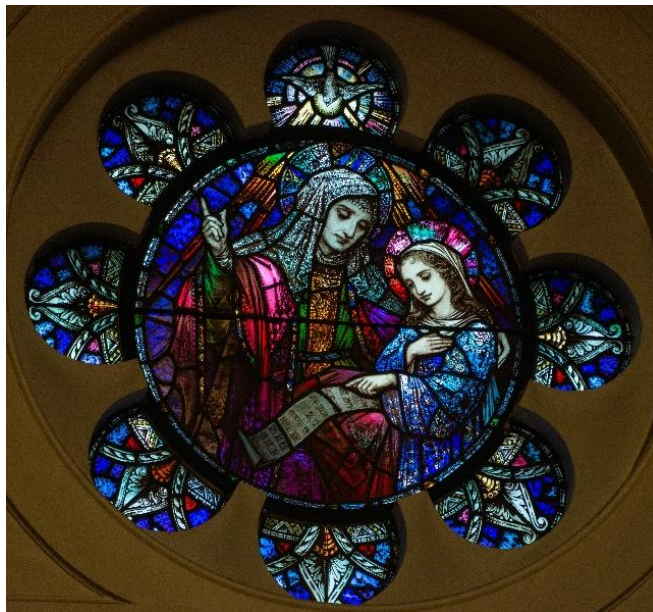


Figure 1.7 Stained-glass window depicting Mary and Saint Anne. Saint Anne was the grandmother of Jesus and the mother of Mary. However, the bible makes no mention of Anne. A book is frequently seen on Saint Anne's lap while she reads to her young daughter. In stained-glass,

religious saints are often associated with specific symbols to identify them, for example, the symbol of Saint Matthew is the angel (Rosewell, 2012).

1.4 Conclusion.

Stained-glass windows are complex visual stimuli that have been created and appreciated for centuries. They can transmit light, which makes them inherently unique. This property can modulate the amount of aesthetic appreciation that individuals have for works of art. In this review, it has been pointed out that a significant gap exists in the literature regarding the influence of light variation on the cognitive processes of the viewer when looking at religious stained-glass, especially on the processes of attention and memory. One of the main factors explaining this gap may be the absence of stained-glass as a visual stimulus used in memory and attention experiments.

In acknowledgement of this gap in the literature, we divided stained-glass windows into their individual components to investigate how these components can influence attentional processes. Light, colour and motion are physical features that can be manipulated by changes in light. Thus, this review addresses how attention is guided to these features in visual array and artworks in eye-tracking studies. We show that the abrupt onset of motion, and contrasts in luminance and colour can attract attention in a bottom-up manner. Next, we investigated how high-level features typically present in stained-glass windows (for example faces, figures, and text) attract attention. Finally, we review how top-down influences such as expertise and religiosity influence the orienting of attention. The final part of this chapter addresses the bi-directional relationship between attention and memory.

Based on the findings revealed in this chapter, we propose that light variation should modulate the distribution of attention of the viewer when presented with images of stained-glass windows. Specifically, attention should be guided via bottom-up attentional mechanisms towards areas that have high luminance intensity and contrast. Additionally, we predict that memory for regions in these windows that have high values in luminance intensity and contrast should be better, due to the bi-directional relationship between attention and memory. Finally, we suggest that light variation that is moving during encoding should result in faster recall and higher recognition performance compared to that of stained-glass windows that are learned with static lighting conditions.

Chapter 2: Selection of Appropriate Stimuli for Subsequent Experimental Chapters

2.1 Introduction

In this chapter, we present the results of a preliminary study aimed at the selection of appropriate images of stained-glass windows as stimuli for the upcoming experiments. The choice of images is a critical element in the research due to the complexity of stained-glass windows and the intricacy of the research questions. As such, this exploratory study lays the foundation for the research endeavours described in the next two chapters, focusing on establishing the groundwork for stimuli selection.

Works of visual art have become more commonly used as stimuli in experimental psychology as the field of neuroaesthetics (the investigation of the cognitive processes involved in aesthetic experience) has become more popular in recent years (Pearce et al., 2016). How to select stimuli from the large variety of available artworks is one of the most difficult methodological problems as the field of empirical aesthetics continues to develop. This selection process of visual stimuli is well documented in relation to the creation of databases for visual artworks such as paintings (Amirshahi et al., 2015; Fekete et al., 2022). In particular, researchers investigating attention and memory processes when viewing artworks attempt to classify these items in a variety of ways, including according to art movement, e.g. Expressionism, Romanticism (Koide et al., 2015; Sharvashidze & Schütz, 2020), visual complexity (Jankowski et al., 2020; Sherman et al., 2015), abstractness (Song et al., 2021), and content (Castellotti et al., 2021).

To the best of our knowledge, stained-glass windows are a type of visual artwork that have not been considered in experimental investigations in the perception of art. Consequently, there is no standard for selecting images as stimuli in empirical studies for this unique medium. Paintings are often made on canvas and are opaque, reflecting and absorbing light. Stained-glass windows, by contrast, are often created from coloured glass, which makes them translucent and allows light to travel through them, which differentiates them from conventional two-dimensional paintings. In addition, leaded lines, are a textured or three-dimensional accent that may be added to stained-glass windows to give the artwork depth and relief. By contrast, most of the time, paintings are flat, and any feeling of relief or texture is limited to painting methods like impasto. These differences may mean that selecting images using the standards utilised to classify paintings may not be the most appropriate method for this study. Stained-glass windows themselves can also differ in terms of style, complexity, formal elements, valency, historical context, presentation quality, genre, and content.

These differences in artworks have been shown to have an impact on cognitive processes, such as aesthetic appreciation (Sherman et al., 2015), attention (Massaro et al., 2012), and memory (Freedman, 1988).

The main aim of this thesis is to investigate the role that light variation has on how one attends to and remembers features depicted in stained-glass windows. Because of this, it was critical to control for any incidental light variation already present in images of stained-glass windows and to ensure that these were not selected as stimuli from our database.

Another variable that we aimed to control was the familiarity of the participant to the specific stained-glass windows that they would be viewing. For the purpose of the research aims in the following chapters, it was important to establish that participants were not familiar with the images of the windows that they viewed. Familiarity is often recorded when creating databases of different types of visual stimuli, for example visual objects (Barbarotto et al., 2002; Brodeur et al., 2010; Viggiano et al., 2004), paintings (Amirshahi et al., 2015; Fekete et al., 2022), and visual scenes (Andrade et al., 2023). Indeed, reducing the probability that participants have had previous exposure to the stimuli used in experiments is crucial in attention and memory experiments as familiarity has been shown to affect eye movement behaviour (Hannula et al., 2010). Accordingly, previous studies have included preliminary surveys on a representative sample of participants to minimise potential familiarity effects in their subsequent studies (Goller et al., 2019). In order to mitigate familiarity risks, research on paintings typically excludes well known paintings as stimuli to avoid effects of familiarity (Sharvashidze & Schütz, 2020). Another approach is to ask participants to record their level of familiarity with each stimulus viewed after the experiment is concluded (Sherman et al., 2015). Because the familiarity of Irish stained-glass windows with the general Irish public is not documented, in this preliminary study, we asked participants to rate how familiar they were with the specific window shown in the image, and to the content that is depicted in these windows. We did this in order to gauge the potential impact of prior exposure to these stimuli as a confounding variable in our upcoming memory experiments, and to assess the level of familiarity of this participant sample to the specific windows presented to them.

This study is exploratory in nature and its primary objective is to establish an optimal database of images of stained-glass windows for use as stimuli in subsequent investigations described in the following chapters. In an online experiment, we presented participants with images of stained-glass windows and asked them to rate each image based on their familiarity with the content depicted in the window, familiarity with the specific window itself, and their perception of how evenly lit the

window was. We calculated the average ratings for each image for each of these three criteria and made our stimulus selections using these data.

2.2 Methods

2.2.1 Participants

42 participants (23 female, $M_{\text{age}} = 35.42$ years, $SD = 10.51$ years) completed this study on the online platform Pavlovia (<https://pavlovia.org/>). A sample size of 40 was determined before recruitment by reviewing relevant prior studies (for example, classifying images on familiarity and visual complexity (Fekete et al., 2022)). Based on a power analysis, we determined that a minimum sample size of 23 participants was required to achieve a statistically significant result with a desired level of statistical power while assuming an effect size of 0.5 and a significance level of $\alpha = 0.05$ in our study.

Participants were recruited using the online platform called Prolific (www.prolific.co). All participants were over the age of 18, located in Ireland and naïve as to the purpose of the experiment. Participants were chosen from Ireland in order to ensure an authentic representation of those who would participate in the subsequent experiments (see Chapter 3).

Participants were compensated £9 per hour for completing the study. On average participants took 20 minutes ($SD = 6$ minutes) to complete this experiment. Informed consent was obtained from all participants in accordance with the procedures that were approved by the Trinity College Dublin School of Psychology Research Ethics Committee [SPREC112022-04] (see Appendix A).

2.2.2 Materials

The starting point for selecting the final set of images for this study was a collection of approximately 1000 images of stained-glass windows from buildings located in the Dublin area, (captured by PhD candidate Stephen Huws). An initial set of 160 images were selected from this database (see Appendix B). Images with text were excluded from this selection, as attention has been shown to have a potential bias towards text (Wang & Pomplun, 2012). This stimuli exclusion process has been used in other studies investigating attention and eye movement patterns (Sharvashidze & Schütz, 2020). For images in which text was located at the bottom of the window, this portion of the window was removed, and the image was retained. Images that included structures that partially blocked the window, for example those including chandeliers or devotional statues, were not included in the final collection of images. Raw images were edited using Adobe Photoshop Lightroom

(<https://www.adobe.com/ie/products/photoshop-lightroom.html>) to centre images and to increase image intensity. The programming platform MATLAB (The MathWorks, Inc. (2022)) was used to resize images to 950 and 600 pixels in height for use in the preview and question portions of the experiment, respectively. The scenes depicted in these 160 images varied significantly in style and content, providing a good sample of stained-glass windows located in the greater Dublin area. All images were presented against a black background.

An original questionnaire of six statements was created for the purposes of this study. These six statements refer to the brightness of the window, familiarity of the participant with the specific window or contents depicted, the scale of the window, and complexity of the window (See Table 2.1). Statements regarding the complexity and size of stained-glass windows were included in this experiment as another researcher investigated the impact of light variation through stained-glass windows on aesthetic perception. For the purposes of this study, data from these statements was not used to inform our stimuli selection. Participants were instructed to rate how strongly they agreed with these statements on a seven-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral, 5 = somewhat agree, 6 = agree, 7 = strongly agree).

Table 2.1 Statements used for the rating study of the perception of stained-glass windows.

Statement Number	Measure	Statement
1	Size Perception	This window is much larger than an average adult.
2	Brightness uniformity	The lighting of this window is evenly distributed.
3	Visual Complexity	Due to the number of different colours used, this window is complex.
4	Visual Complexity	Due to the number of pieces of glass used, this window is complex.
5	Familiarity	I am familiar with this specific window.
6	Familiarity	I am familiar with the story and/or character(s) depicted in this window.

2.2.3 Design

We wished to collect 10 responses per question, per image. With a dataset of 160 images, this would require 40 participants to generate this number of responses. Participants were randomly assigned to one set of 40 images within the 160-image database. We counterbalanced the pool of 40 images that participants would rate to ensure that each image would be seen, and consequently be rated, by exactly ten different participants. Participants would complete 40 trials, in which one image would be presented and rated in each trial. The order of image presentation was randomised across participants.

2.2.4 Procedure

The study was created using the psychophysics software PsychoPy (<https://www.psychopy.org/>). Data were collected using the online version of this software, Pavlovia (<https://pavlovia.org/>). Before starting the experiment, participants were provided with a Participation Information Sheet which detailed the experimental procedures. Once the experiment was started online, participants were informed about their data management and were given the opportunity to consent. If consent was not obtained, the experiment was terminated. To ensure that the images of stained-glass windows would be viewed on a larger screen, we made it a requirement for the study to be completed on a desktop computer rather than a tablet or smartphone. Participants could not continue with the experiment unless they pressed the spacebar, which was a feature that enforced this requirement.

Once consent was obtained, three practice trials gave participants the opportunity to learn the trial design and to ensure that they understood the rating task. Following completion of the practice block, the experimental trials began. Each trial started with a fixation cross presented on the screen for 500 ms, after which an image of a stained-glass window was presented for five seconds. Following this preview image, a smaller version of the same stained-glass window image appeared on the screen, accompanied by one of the six statements described in Table 2.1. Participants were asked to respond to each statement via a seven-point Likert scale and were advised to answer as quickly and as accurately as possible. Once a response was registered, this statement was replaced by a new statement from the possible pool of six. The presentation order of these statements was randomised across trials. Participants would see a screen requesting a quicker response if 30 seconds went by without a response being recorded. Once all statements were answered, a blank screen would appear

for 500 ms, and the trial block would repeat for the next stained-glass window image. An example of a trial sequence is illustrated in Figure 2.1.



Figure 2.1 An example of rating study trial sequence.

Following completion of the study, participants were provided with debriefing information, explaining the purpose and the procedures of the study.

The average rating response was calculated for each image across all participants using the programming language R (R Core Team (2023)) to determine which images should be excluded (see Appendix B). A median split was employed to dichotomize participant responses. Specifically, the cut-off was set at replies with a median value of 4 (which denotes neutrality on the scale). Images for which participants' average ratings for window familiarity exceeded this threshold (i.e., had an average greater than four) were excluded from our database. This exclusion criterion was applied to ensure that only images for which participants expressed a lower level of familiarity were retained for subsequent analyses. An identical threshold was applied for responses for the uniformity of brightness, however in this case, images for which participants' average ratings for brightness uniformity were less than this threshold (i.e., had an average less than four) were excluded from our database.

2.3 Results

2.3.1 Participant exclusion

76 participants clicked the link to participate in our study on Prolific. However, due to a technical issue that was later resolved, a long loading time (mean time = 16 min), resulted in 24 participants exiting the study loading screen before the experiment began. The remaining 52 participants began the initial experiment, with three failing to consent and 42 completing the entire experiment (see Figure 2.2).

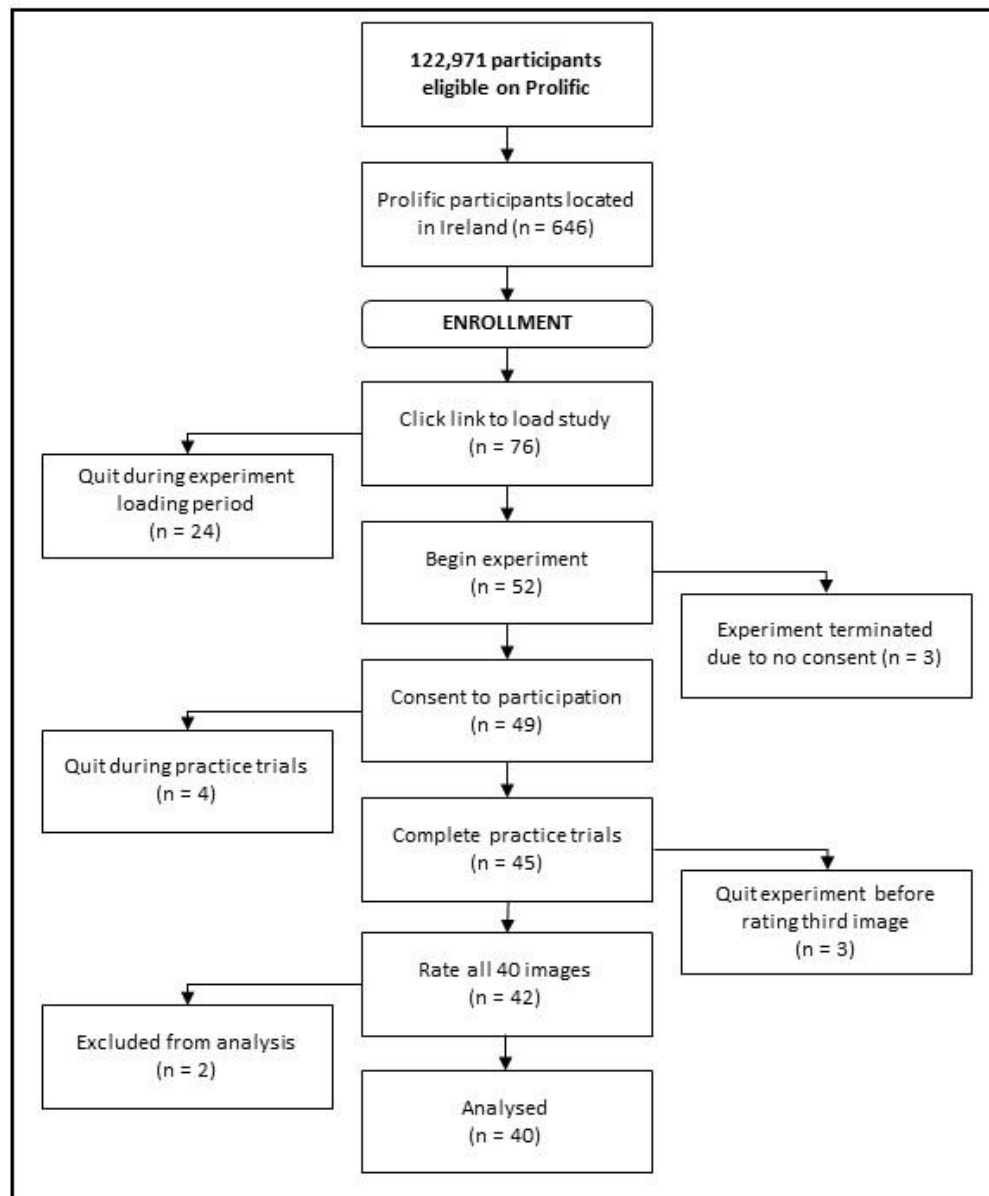


Figure 2.2 Schematic illustration of Participant Selection during Rating Study.

Participants who consistently provided uniform responses in the Likert scale (e.g., consistently selecting 'somewhat agree' with a rating of 5) for 70% or more of the statements were deemed to have provided non-varied responses and their data were also excluded from the analysis. This threshold was chosen to ensure that excluded participants displayed a consistent pattern of responding. One participant met this exclusion criterion.

Due to a technical mistake in which the image of a stained-glass window concealed the statements displayed on the rating screen, the data from a second participant was removed because it was not possible for them to reply meaningfully to each statement.

2.3.2 Statistics and Data Analysis

Analyses were conducted solely on the following measures: familiarity of the participant with the specific stained-glass windows, familiarity of the participant with the character(s) and/or story depicted in the stained-glass window and distribution of light through the window. The mean evenness of brightness distribution for each window ranged from 1.9 to 6.4 ($M = 4.99$, $SD = 0.73$). The mean window familiarity scores of all the images of stained-glass windows ranged from 1.3 to 4.4 ($M = 2.42$, $SD = 0.57$). The mean familiarity of participants with the character(s) and/or stories depicted in these windows ranged from 1.3 to 6.3 ($M = 3.55$, $SD = 1.16$).



Figure 2.3 Boxplot of average responses for different statements.

A cut-off for stimulus exclusion was applied to our database by eliminating pictures that received an average familiarity rating of four or higher and an average rating of brightness uniformity of four or lower. Twelve images received average ratings of below four on evenness of brightness (the two images with the lowest average ratings for evenness of brightness are illustrated in Figure 2.5A). Two images received an average rating of greater than four for familiarity and were not included in the final sample (see Figure 2.6A). As a result, 14 images were not included in the final sample from our initial collection of 160, leaving 146 images of stained-glass windows which met the criteria to be used as stimuli in the later experiments.

The ratings for the familiarity of the participants to the content depicted in the windows displayed a wide and diverse distribution across the images. This broad distribution suggests that applying a median split to the dataset, which is typically used to dichotomize data into high and low categories, may not be suitable in this context. The reason for this is that the familiarity ratings spanned a continuum from very unfamiliar (see Figure 2.7A) to highly familiar (see Figure 2.7B), with many responses clustering around the neutral midpoint of the scale (see Figure 2.3). This distribution underscores the complexity of participants' perceptions and highlights that content familiarity in this study does not conform to a simple binary classification. As a result, content familiarity was not used as a measure for image exclusion in this analysis.

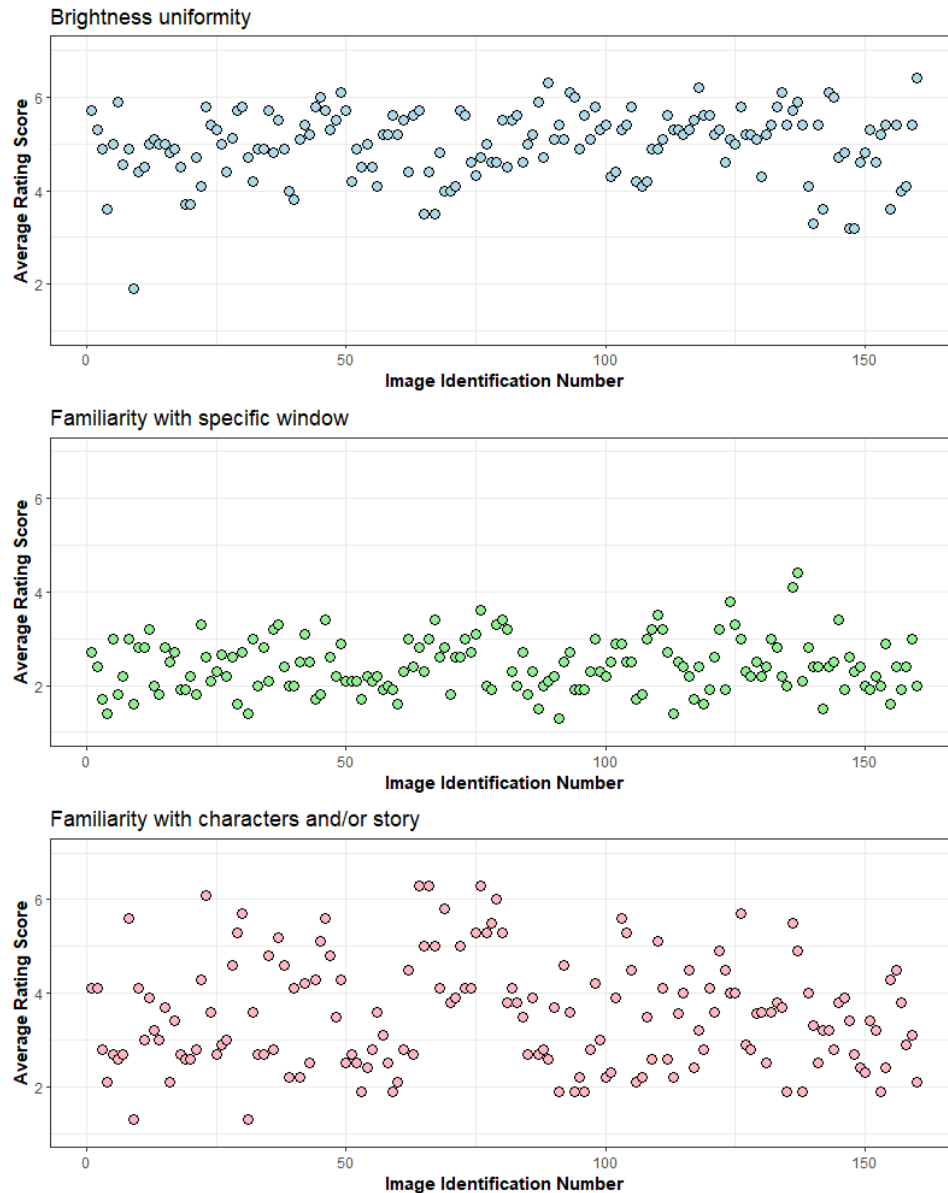


Figure 2.4 Plots showing the average ratings for each individual image vis-à-vis each of the dimensions tested. Images are issued a unique identification number from 001 to 160, and these identification numbers are used in both the following in-person and online attention and memory studies (chapters three and four respectively). The original image names for each of these stained-glass windows can be found in Appendix B.

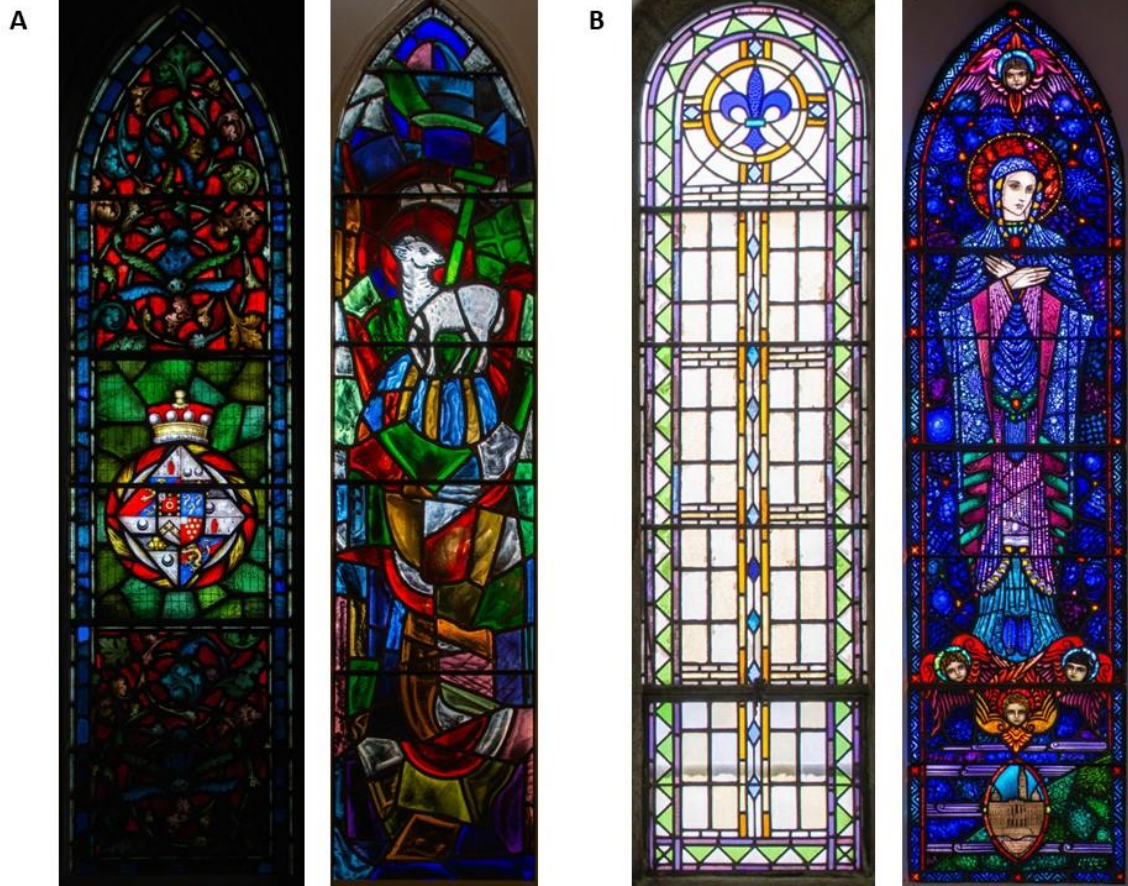
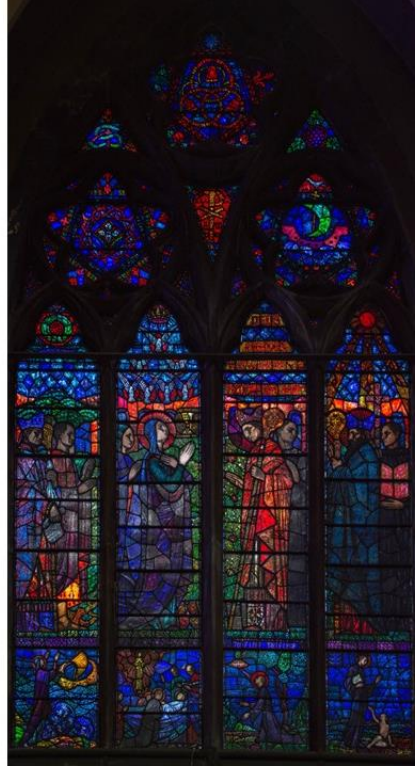


Figure 2.5 Examples of images of stained-glass windows with the lowest (a) and highest (b) average ratings for uniformity of brightness distribution. From left to right, images have a mean score of 1.9 ($SD = 1.37$), 3.2 ($SD = 1.75$), 6.4 ($SD = 0.70$) and 6.3 (0.67), respectively.

A



B



Figure 2.6 Stained-glass windows with the lowest (a) and highest (b) average scores for familiarity with specific window. From left to right, images have a mean score of 1.3 ($SD = 0.48$), 1.4 ($SD = 0.52$), 4.4 ($SD = 2.17$) and 4.1 ($SD = 2.60$), respectively.

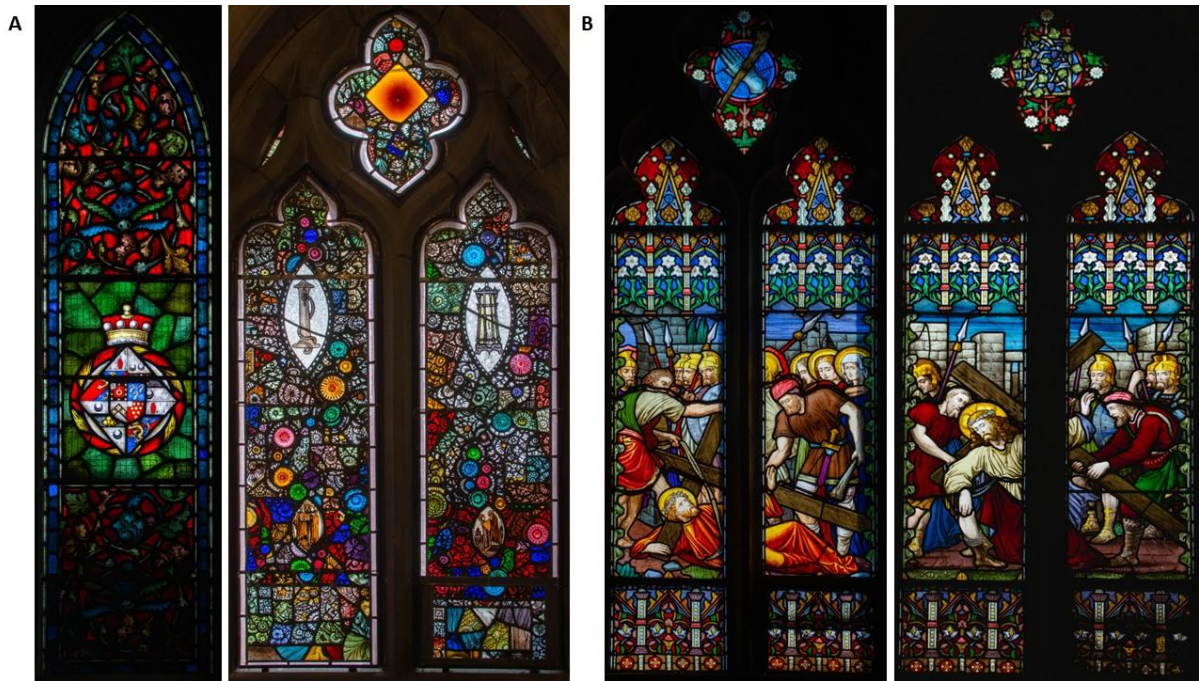


Figure 2.7 Stained-glass windows with the lowest (a) and highest (b) average scores for familiarity with character(s) and/or story. from left to right, images have a mean score of 1.3 (SD = 0.48), 1.3 (SD = 0.67), 6.3(SD = 0.82) and 6.3 (SD = 0.67), respectively.

2.4 Discussion

At the time of writing, no investigations had been conducted on images of stained-glass windows. In our results, most images were rated as having an even distribution of lighting transmitting through them. As images with obvious shadows and light patterns had been removed from the original collection of images before the rating study was carried out, these results help us to narrow down our selection further. The results from this study can be visually verified by looking at the windows that were rated as having an uneven distribution of brightness, for example, image 009 has a dark shadow in the lower half of its frame (see Figure 2.5).

We asked participants to rate images based on how familiar they were with the specific window that was presented to them. Despite recruiting a participant sample of those located in Ireland, only two windows were considered familiar. From these results, it may be suggested that the wider public in Ireland do not possess a high degree of familiarity with specific stained-glass windows, thus preexposure to stimuli in future experiments may not be a potential confounding variable.

The distribution of average responses for familiarity of the content depicted in stained-glass windows is uniformly distributed. The stained-glass windows that rank low on story familiarity are those that do not depict figures (see Figure 2.7). Windows that are rated as containing highly familiar content depict stories of Jesus and the Stations of the Cross.

A possible limitation of this study is recruitment concerns due to technical difficulties experienced by the first half of participants. Long waiting periods may have caused participants to become fatigued before the experiment began, which may have contributed to some participants finishing the experiment in a very short period (less than 10 minutes).

In conclusion, the ratings we collected in this study were an essential tool in the image selection process that will allow us to compile a diverse set of images that will allow us to fulfil the research objectives in our future studies. These windows possess an even distribution of lighting and are unfamiliar to the Irish population, features that are vital in stimuli to be used in the future investigation of the effects of light variation in stained-glass windows on attention and memory.

Chapter 3: The Role of Light Variation on Attentional Allocation and Memory for Features Depicted in Stained-Glass Windows: An Eye-Tracking Study.

3.1. Introduction

When people recount their experience after viewing stained glass windows, the lighting coming through the windows and how this lighting made them feel is frequently mentioned (Day, 1909). In this study, we are interested in how the interaction of light and the images portrayed in these exquisite works of art can influence the allocation of attention and improve memory for the viewed features of these stained-glass windows. If lighting in stained-glass windows can attract attention, how might this be done? William James (1890) recognized that the viewer's expectations and goals, as well as the characteristics of the visual stimulus, can influence how his or her attention is deployed when viewing visual stimuli. Current theories of attention support this idea and suggest that attention is directed in both a bottom-up (stimulus driven) and top-down (goal-directed) manner (Egeth & Yantis, 1997).

Bottom-up attention orienting mechanisms are activated by the properties of a stimulus (for example, colour, edge density, orientation, and luminance) and is directed in an involuntary manner to areas with a high contrast in these visual features (Wolfe, 1994). Feature singletons that vary on intensity in one of these dimensions can aid visual search for these items in a process in which the singleton 'pops out' from other homogenous distractors in the array and can be rapidly detected (Treisman, 1985; Wolfe, 1994). According to Treisman's Feature Integration Theory (Treisman & Gelade, 1980) in the first stage of viewing a visual stimulus, bottom-up attentional guidance is observed as the visual system pre-attentively processes all incoming visual information equally and in parallel. This rudimentary feature information is filtered and analysed to determine what visual information may pass the attentional bottle neck and proceed to the second stage of visual information processing where a limited amount of information can be processed in a high level of detail (Broadbent, 1958; Treisman & Gelade, 1980).

The theory that visually salient regions in a visual field can draw bottom-up orienting mechanisms is the foundation for computational modelling of attention (Koch & Ullman, 1985; Zhaoping, 2005). In this framework, it is theorised that feature maps are created that quantify the amount of a visual information at each location in the visual field and include dimensions for colour, orientation, luminance intensity, etc. These feature maps are combined in a 'winner-takes all' approach to create a topographically organised saliency map that maps intensity values at each location in the visual field.

Attention is directed in a linear fashion to the areas with the highest saliency value to the next location. There is evidence to suggest that this effect is seen in the first few fixations of scene viewing, immediately after stimulus onset (Parkhurst et al., 2002). It has been demonstrated that fixations are drawn to regions that contain higher values of local contrast and edge density compared to other regions in complex scenes (Mannan et al., 1996, 1997; Reinagel & Zador, 1999). According to visual array studies (Theeuwes, 1995; Turatto & Galfano, 2000), luminance intensity contrast and colour in feature singletons have been shown to draw attention in a bottom-up fashion during visual search tasks.

When viewing artworks, the number of fixations to any one location is affected by the visual properties of the stimulus (Fuchs et al., 2011), especially in bright areas juxtaposed on a dark background (Fontoura & Menu, 2021; Winter et al., 2022). Despite this knowledge, artworks that rely on the fluctuations of their physical characteristics (i.e light and luminance contrast) such as stained-glass windows have yet to be researched. Based on the theories described above, light variation in stained-glass windows, for example a patch of light shining through a small area, is likely to attract attention via bottom-up attention orienting mechanisms immediately after stimulus onset.

However, attention drawn to areas with light variations in stained glass windows may also have to compete with top-down attentional mechanisms directing gaze towards features depicted in these windows. For example, previous studies suggest that observers fixate on areas within images of complex scenes that are thought to be semantically informative (Mackworth & Morandi, 1967). Objects such as faces in a scene have been shown to attract attention, as observers preferentially look at faces and figures in visual stimuli (Buswell, 1935; Yarbus, 1967), suggesting a significant role of top-down influences in visual processing. New-born infants have been shown to have a unique sensitivity to faces and face-like stimuli as early as one hour after birth (Johnson et al., 1991). In visual search tasks, when images of faces act as targets this results in shorter search times and greater number of direct saccades compared to non-facial stimuli (Morrissey et al., 2019). When viewing artworks, attention is typically drawn to the key figures depicted in these paintings (Winter et al., 2022). The goals and intentions of the observer has also been shown to affect the deployment of attention (Posner, 1980), so the specific instructions that participants are given during eye-tracking and attention studies need to be carefully chosen for your research question. Expertise, another form of top-down influence, has been shown to influence gaze patterns in eye-tracking studies involving paintings (Pihko et al., 2011; Sharvashidze & Schütz, 2020).

Prior knowledge from memory can guide the allocation of attention in a top-down manner. For example, previous exposure to stimuli can affect gaze patterns (Hannula et al., 2010). Semantic inconsistencies, such as items that are inconsistent with scene context, attract greater and longer eye fixations than items that are semantically consistent within the scene (Henderson & Hollingworth, 1999; Loftus & Mackworth, 1978b; Vo & Henderson, 2009). When viewing a stimulus for a second time, the scan paths of participants differ from those during the initial viewing (Noton & Stark, 1971). Indeed, memory and attention are so intrinsically linked that not only can memory affect the deployment of attention, but attention can also influence the encoding of memory. For example, the division of attention during encoding negatively affects memory performance (Chun & Turk-Browne, 2007), suggesting that overt attention is required for the successful encoding of information in memory stores. Attention is also required to successfully bind and maintain features in working memory (Zokaei et al., 2013).

Based on the findings discussed above, we propose that the relationship between attention and memory will influence memory recall for regions of images of stained-glass windows. In the following study we were particularly interested in whether light variation across an image of a stained-glass window, in which one region would be more brightly lit than other regions, would affect attentional allocation and subsequent memory of the features within that region than regions that are not brightly lit. We examined how features portrayed in images of stained-glass windows are attended to and remembered under different light conditions. To do this, we generated images of stained-glass windows with three different light conditions; images either maintained their original diffuse lighting or had a patch of light in the facial region of the image or in a background region. Whilst participants freely viewed images of stained-glass windows in one of these three light conditions, their eye movements were monitored. Then, in a subsequent memory test, we recorded response times and accuracy using a two-alternative forced choice design to compare memory accuracy and response time between these light conditions. Images of stained-glass windows with only one facial feature were included in this study, and the influence of patches of light to orient attention away from semantically salient features such as a face was investigated. We predicted that light variation in the form of light patches located in background regions of a stained-glass window would be able to draw attention away from facial regions depicted in these windows. This would be expressed by an increased number of fixations and fixation duration in the background region for images with light patches in this area, compared to the images of the same stained-glass window presented in the diffuse condition or in the facial light patch condition. We also predicted that memory for background

regions would be improved by the presence of light patches in these regions. As a result, there would be better memory accuracy and shorter response times for identifying background segments for images that were presented in the ‘background light patch condition’ compared to those presented in the facial light patch and diffuse conditions.

3.2 Methods

3.2.1 Participants

The sample size for this study was set with an a priori stopping rule of 89 acceptable participants based on a power analysis conducted in the power analysis program PANGAEA (Power ANalysis for GEneral Anova designs; <http://jakewestfall.org/pangea/>) and an effect size of 0.25. However, due to time constraints, only 21 participants had completed this study at the time of writing. As a result, this study was underpowered.

Twenty-one participants (14 females, 7 males; $M_{\text{age}} = 26.57$ years, $SD = 7.68$) completed this study. Participants were recruited via recruitment posters placed on Trinity College Dublin campus or by word of mouth. All participants were over the age of 18, resident in Ireland and naïve to the purpose of the study. 18 participants had completed third level education, 3 participants had the highest education level of secondary school. Eighteen (86%) of participants reported not being religious. All participants provided informed consent prior to conducting the experiment. All participants reported normal or corrected-to normal vision.

Participants were given the option to be compensated for completing the study with either a €5 TCard top-up or a €5 National Book Tokens e-Gift card. On average, participants completed the study in 15.68 minutes ($SD = 3.27$ minutes). Written informed consent was obtained from all the participants in accordance with the procedures that were approved by the Trinity College Dublin School of Psychology Research Ethics Committee [SPREC112022-04].

3.2.2 Materials

In Chapter 2 we established a database of 148 stained-glass window images that were rated as novel to the sample of participants resident in Ireland, have an even distribution of illumination and are free of text, obstructions, and shadows. In this study we aimed to investigate how light variation might be able to compete with attentional bias towards semantic features such as faces. To control for the number of faces present in each stained-glass window, we included images that contained only one figure. We also removed images that had a width larger than 3 standard deviations

from the mean width of all images in the database. This threshold was applied to prevent segment width being used as a distinguishing feature in the memory task. The 29 remaining images of windows used in this study are listed in Appendix C.

To investigate the effect of light variation on attention and memory, three versions of each of the 29 images of stained-glass windows were generated for use in this study: a diffuse light condition in which there was little variation of light intensity across the image, and two intense light patch conditions in which a patch of light was applied specifically to one of two regions on the image: the facial region or to a background region. To create these images, we used the creative coding program Processing (<https://processing.org/>). First, images were loaded into the sketchbook and a binary mask was applied to each image. A different binary mask threshold was required for each image due to variation in stained-glass patterns, different contrasts, colour variation and image noise. After this threshold was applied, a light patch (75 pixels in diameter) was applied to the facial region and a background region of each stained-glass window image. The RGB values for the midpoint colour and the inner colour of this light patch were (20, 200, 255) and (40, 40, 255) respectively. Images were then placed on a black background of size 1920 x 1080 pixels using Photoshop (Adobe Inc. 2019). The diameter of the intense light patch was 2.1 cm. When presented on a screen of width 60.5 x 35.5 cm and at a distance of 60 cm, this circle subtended a visual angle of approximately 1.1 degrees.

Images for use in the memory task were created by splitting each of the original target images (29) into 12 segments using the programming language MATLAB (The MathWorks Inc. (2022)). See Figure 3.1. The purpose of this segmentation was to provide stimuli for the test phase of the experiment. In a pilot study, the target images were divided into six segments, however ceiling effects were observed. To reduce this effect, the target images were instead divided into 12.

From the original database (see Chapter 2) we selected (87) images as distractor images to use during the memory test. Images were selected so that they matched the original images were for content, panel size, colour, and window shape. Thus, each of the original target images were matched with 3 independent stained-glass window images along these constraints. See Figure 3.2 for an example of matched images. As with the targets, distractor images were also divided into 12 equal sized segments.

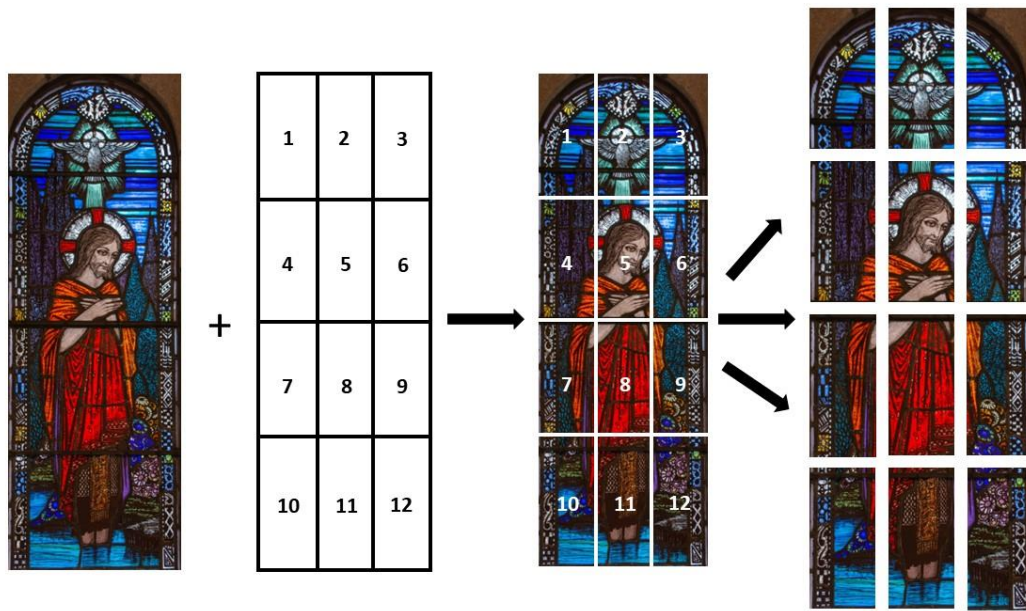


Figure 3.1 The process of dividing stimuli into 12 segments for use in the memory task. Images were divided into 12 equally sized segments, which were given a unique number code denoting the location of this segment in the original image. In the memory task, segments from the same location from the target image and the distractor image are presented to the participant. Image ID “042” is used as an example in this figure.

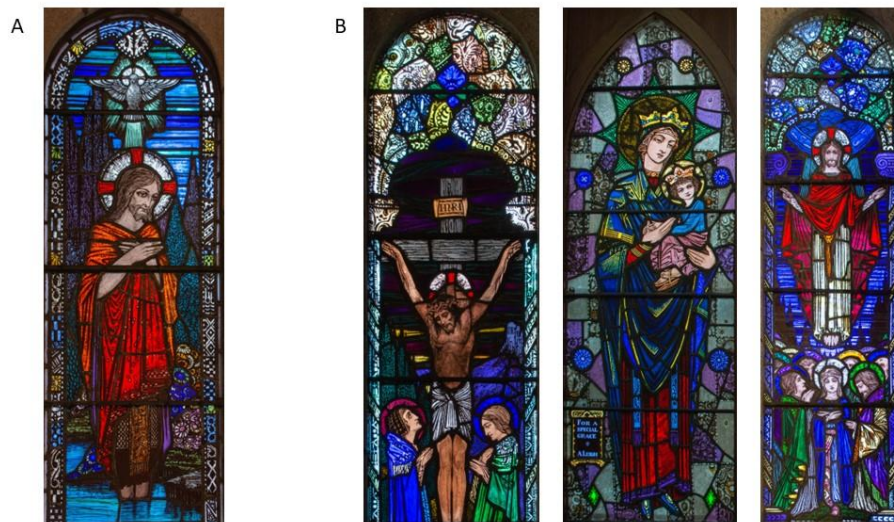


Figure 3.2 Example of three images selected to be used in the memory task for image ID “042”. The matched images were selected based on similar colour schemes, content, panel size and window shape.

3.2.3. Apparatus

The study was performed in a quiet and dark room. During the experiment participants' heads were stabilised using a head and chin rest (unrestrained) to maintain a constant 60 cm distance between the participants eyes and the screen (1920 x 1080 pixels, 60 Hz). At a distance of 60cm from the screen, scenes subtended approximately 64° x 34° of visual angle at 60.5 x 35.5 cm. The stimuli that were presented on the monitor were controlled using PsychoPy version 2023.1.0. (Peirce et al, 2019). Participants' eye movements were recorded at 60 Hz using a monitor mounted Tobii Pro Fusion (<https://www.tobii.com/resource-center/webinars/introduction-to-tobii-pro-fusion>). Viewing of scenes was binocular and data was recorded from both eyes.

3.2.4 Design

The experiment used a one-way within-subjects design in which the independent variable was light variation condition with three levels: diffuse lighting (no light patch), light patch on a facial region and light patch on a background region. The dependent variables were fixation number, total fixation duration per trial during the learning phase and response times and accuracy during the memory test. All 29 images were shown to each participant across the three light conditions in a randomised order. As a result, participants each completed 87 trials.

3.2.5 Procedure

Before starting the experiment, participants were provided with a participation information sheet which detailed the basic experimental procedures that they would experience. After written consent was obtained from the participant, a demographic questionnaire was filled out. Participants were asked to report in the questionnaire their age in years, sex at birth, highest level of education completed, which of their eyes is stronger, and their level of religiosity. Religiosity was recorded on a seven-point Likert scale where participants were asked “On a scale from one to seven, how religious would you consider yourself?” where 1 is equal to “not at all” and 7 is equal to “very religious”. Participants were also asked to record which religious affiliation that they would most closely identify with.

To record eye movements the eye-tracking experiment, observers sat down in front of the screen in a quiet and dark room. At the beginning of the experiment, calibration and validation for eye tracking were preformed using a 9-point procedure. Participants were then informed that they would be presented with images of stained-glass windows and would be asked to complete a memory task after each image was presented.

The experiment began with 3 practice trials. Next, the main experiment was conducted. The experiment consisted of 87 trials and the order of trials was randomised for each participant. Each trial began with a display of a black screen for 500 ms, followed by the presentation of a central fixation cross for 500 ms, which was used to return the participants' point of gaze to the centre of the screen between images. Then, a single image of a stained-glass window was presented for a four second duration. Participants were instructed to view and memorise the image of the window.

After a duration of four seconds, the stained-glass image was replaced with two smaller images side by side. Participants were asked to indicate via key press whether the image on the right or the image on the left contained a segment taken from the target image (i.e., that they had just been asked to memorise on the previous screen). Participants were instructed to respond as quickly and as accurately as possible. Once a response was recorded, a new trial would begin. A sample trial is illustrated in Figure 3.3.

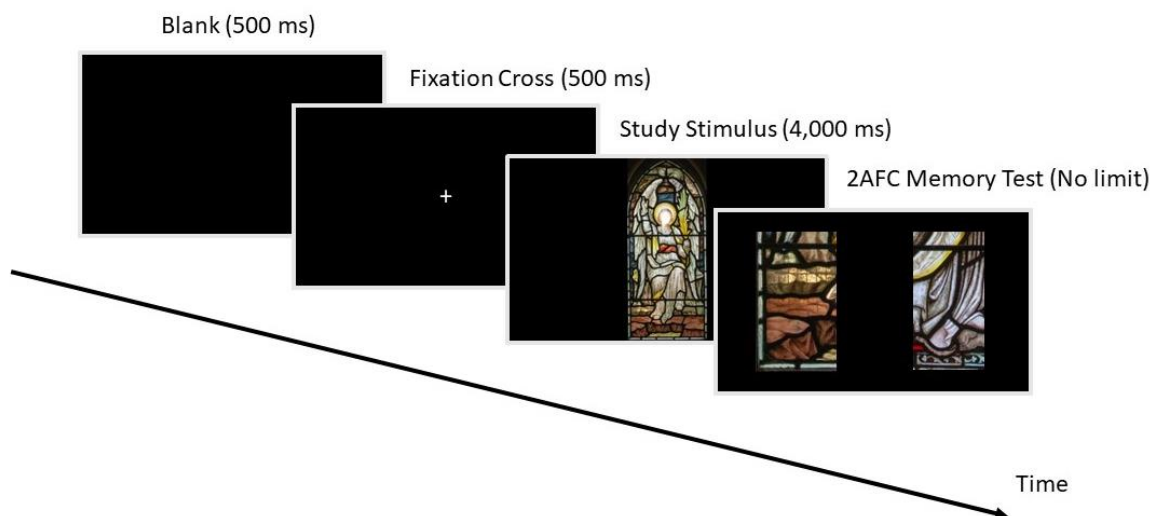


Figure 3.3 Example of a trial sequence in this study. A blank screen and a fixation cross are shown sequentially for 500 ms each.

Following completion of this study, participants were provided with debriefing information explaining the purpose and the procedures of the study. The average amount of time for the completion of the entire experiment was 16 minutes (SD = 3.27 minutes).

3.2.6 Analysis

The eye tracking data of 20 out of 21 participants were analysed. The data of one participant was not analysed due to the participant keeping their eyes fixated in the centre of the screen for the duration of the experiment. The HDFViewer tool was used to export the raw eye-tracking HDF5 file data to a text file, which was then read into R for additional processing. The eye-tracker camera delivered a 1920 x 1080 image with the gaze coordinates available in pixels. Starting at the video frame in which the participant first saw the image, four seconds of data from each participant's image previewing were retrieved and blinks were removed.

Each face was encompassed by a circular region of interest (ROI) of 75 pixels. Another circular ROI of the same size encompassed the background region where the background light patch could potentially inhabit. The ROIs were used to define fixations on the face versus the background location. These ROIs recorded fixation number and fixation duration to these regions during the memorisation phase of the experiment. The location of these ROIs differed for each image but remained the same for each version of each image.

The number of fixations and total fixation duration was recorded for both the facial ROI and the background ROI of each light condition version of each image. In order to examine whether the number of fixations and total fixation time in these locations differs across the three conditions, we performed a one-way ANOVA with light condition as the within-participant factor. To investigate if there is a main effect of light condition on memory accuracy, a chi-square test of independence was performed. In addition, a one-way ANOVA was performed to investigate if there was a main effect of lighting condition on response time. Finally, we generated heat maps across all image versions.

3.3 Results

Following completion of the experiment, one participant revealed that they had not understood the instructions of the study task and had stared at the centre of the screen for the entirety of the experiment. As a result, their data were not included in the analysis.

To investigate the distribution of attention between light conditions, heatmaps were generated for each version of each image. To create a continuous fixation density map of an image

from the eye tracking data of all subjects, we overlayed all fixation points from all viewers for each image. This map was then smoothed with a Gaussian kernel (bandwidth = 50). In Figure 3.4 the three versions of images 107, 089 and 043 are shown. The first panel shows the diffuse condition of each image, the third panel illustrates the facial light patch condition, and the fifth panel contains the background light patch condition. Beside each image version is the associated heatmap generated from the gaze data collected from our 20 participants. In this figure, attention was not uniformly distributed across the stained-glass window images, but concentrated on specific elements, namely the faces of the figures depicted in the stained-glass windows. This effect was observed for each light variation image type. Few fixations fell upon the light patches that occupy the background regions in these heatmaps. It is noteworthy that a centre image bias was also present in all light variation conditions.



Figure 3.4 Heatmaps were created using the gaze data from all 20 participants for each of the three lighting conditions. Images 107, 089, and 043 are displayed in the top to bottom rows, respectively. The diffuse light version of each stained-glass window image and its corresponding heatmap are displayed in the first two panels of each row. The original facial light condition and its associated heat map are shown in the following two panels, followed by the background light patch condition and its related heat map in the following two panels.

The number of fixations per ROI was recorded during the learning phase of each trial. A violin plot of the number of fixations recorded in the facial ROI of an image per light condition is shown in Figure 3.5. A one-way ANOVA between the three light conditions revealed that there was no significant difference in the number of fixations recorded in the facial area when light variation was present in the image ($p = 0.61$).

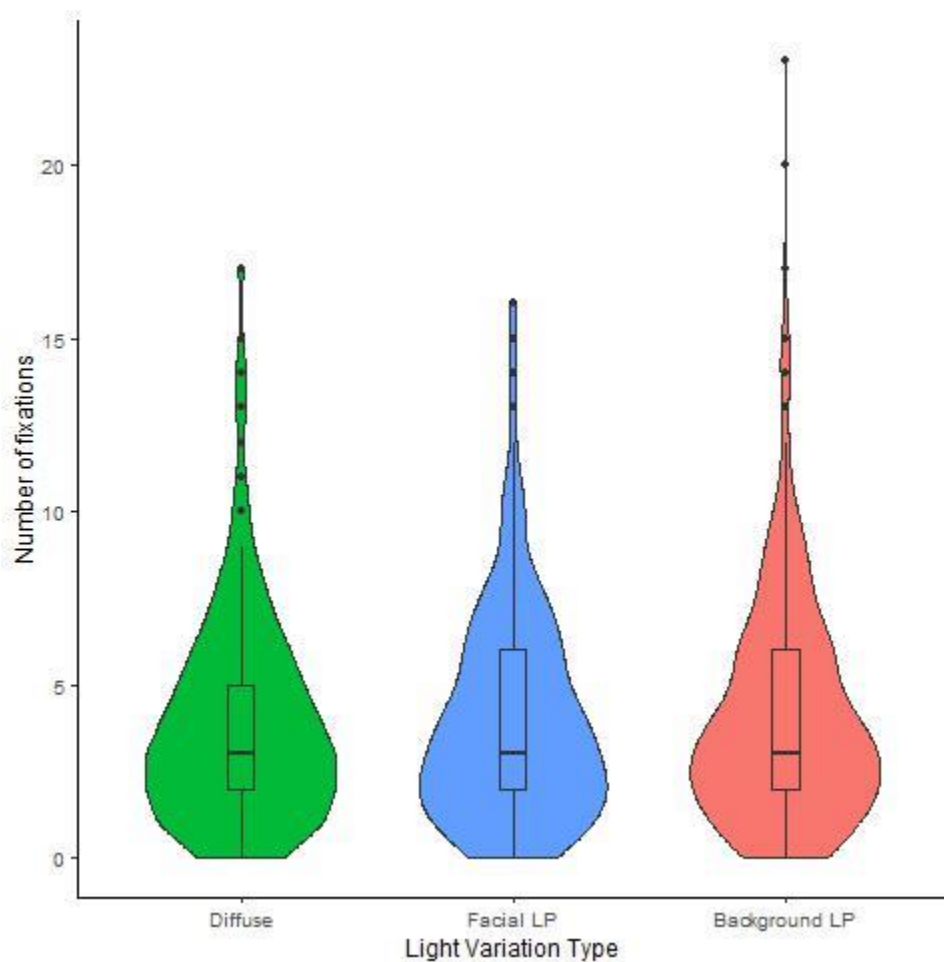


Figure 3.5 The number of fixations recorded in the facial ROI per light variation condition per trial.

There was no significant difference in the number of times participants fixated within the facial region of a stained-glass window, regardless of light variation condition. "Diffuse" refers to images without light manipulations applied to them. "Facial LP" refers to images that had a light patch applied to the facial region and "Background LP" refers to images with a patch of light located in a background region.

A one-way ANOVA between the three light conditions for fixation number in a background ROI resulted in an overall main effect of light condition, $F(2, 1737) = 7.848$, $p < 0.001$ (see Figure 3.6). A post hoc Tukey test showed that there was a significant difference in means between the images with the light patch applied to the facial region and the images with the light patch applied to the background region ($p = 0.0029$). There was also a significant difference in means between the diffuse group and the facial light patch group ($p = 0.0011$), however, there was no difference observed in fixation number in the background ROI between background light patch images and the diffuse images ($p = 0.97$).

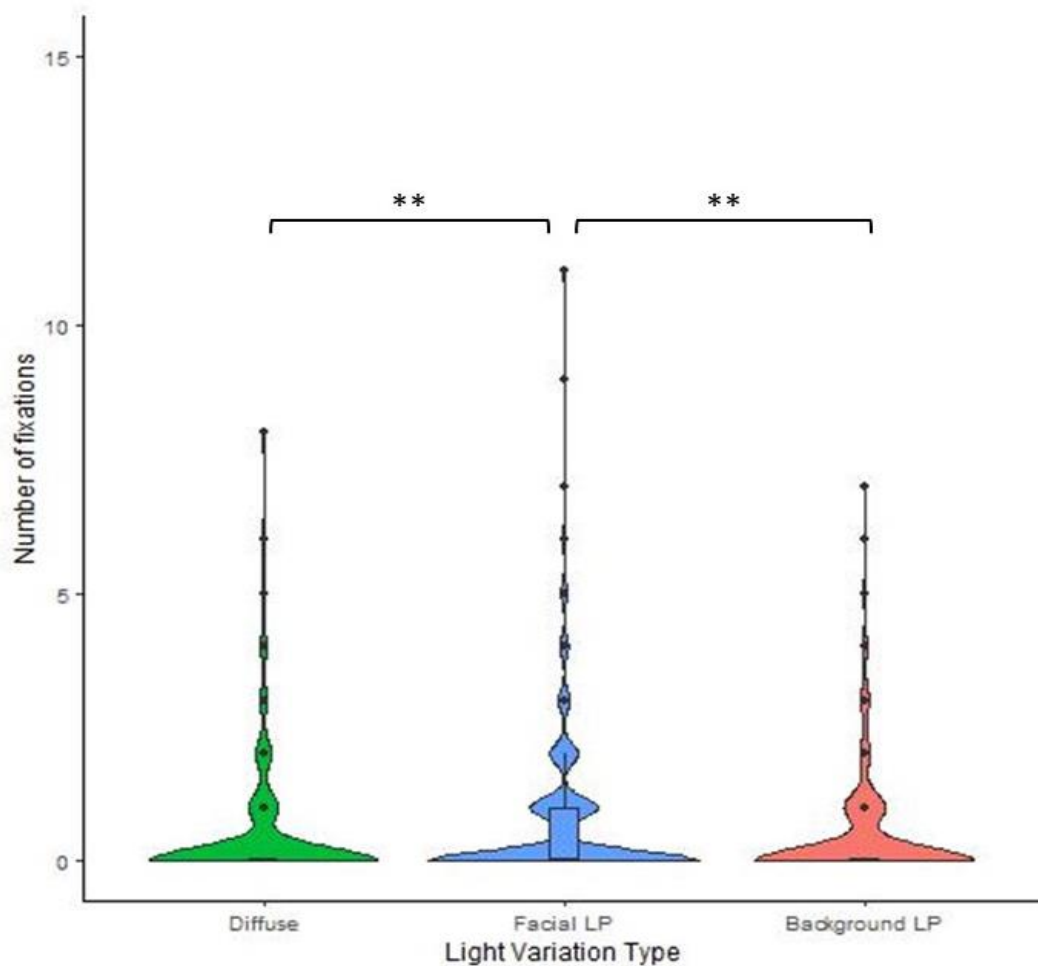


Figure 3.6 The number of fixations recorded in the background ROI of each image per light condition. “Diffuse” refers to images without light manipulations applied to them. “Facial LP” refers to images that had a light patch applied to the facial region and “Background LP” refers to images with a patch of light located in a background region.

The total amount of time spent fixating on the facial or background ROIs was calculated in R. A one-way ANOVA found the effect of the light variation factor on total fixation duration to be statistically significant, $F(2, 1732), p < 0.001$ (see Figure 3.7). A post hoc Tukey test was performed to investigate which light condition had the effect. A significant difference in fixation duration was observed between images with a light patch applied on a facial feature and those with a light patch placed on a background feature ($p < 0.001$). The amount of time spent looking in the background ROI

was also significantly increased when there was a light patch in the facial region compared to when there was no light patch at all ($p < 0.0001$).

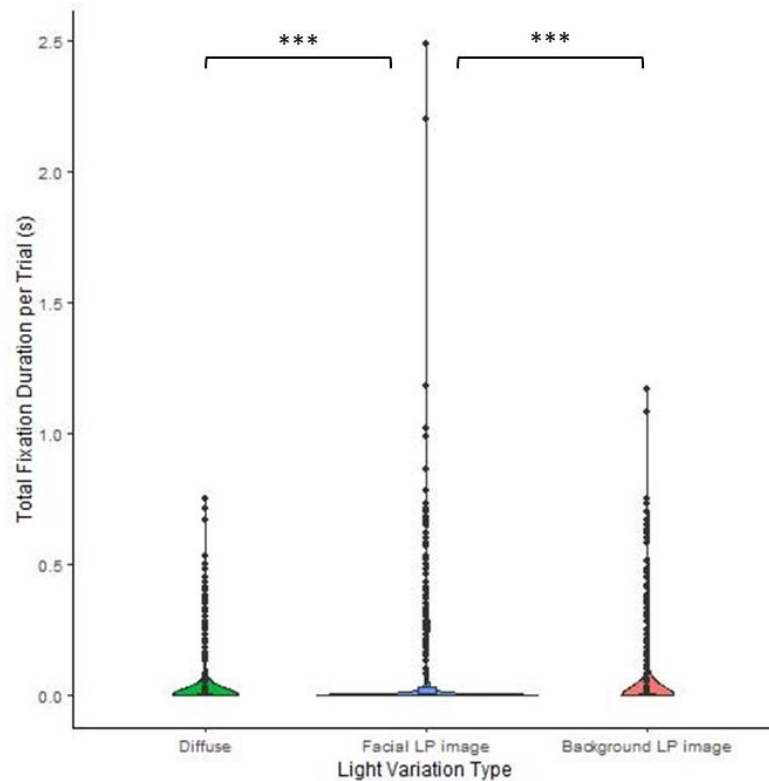


Figure 3.7 Fixation duration in background ROI per light condition. There is a significant effect of light condition on fixation duration in background feature region of interests. “Facial LP” refers to images that have a light patch applied to the facial region and “Background LP” refers to images with a patch of light located in a background region. “Diffuse” refers to images with no light manipulations.

Conversely, light condition was not significantly related to fixation duration to the ROIs on the face features (see Figure 3.8).

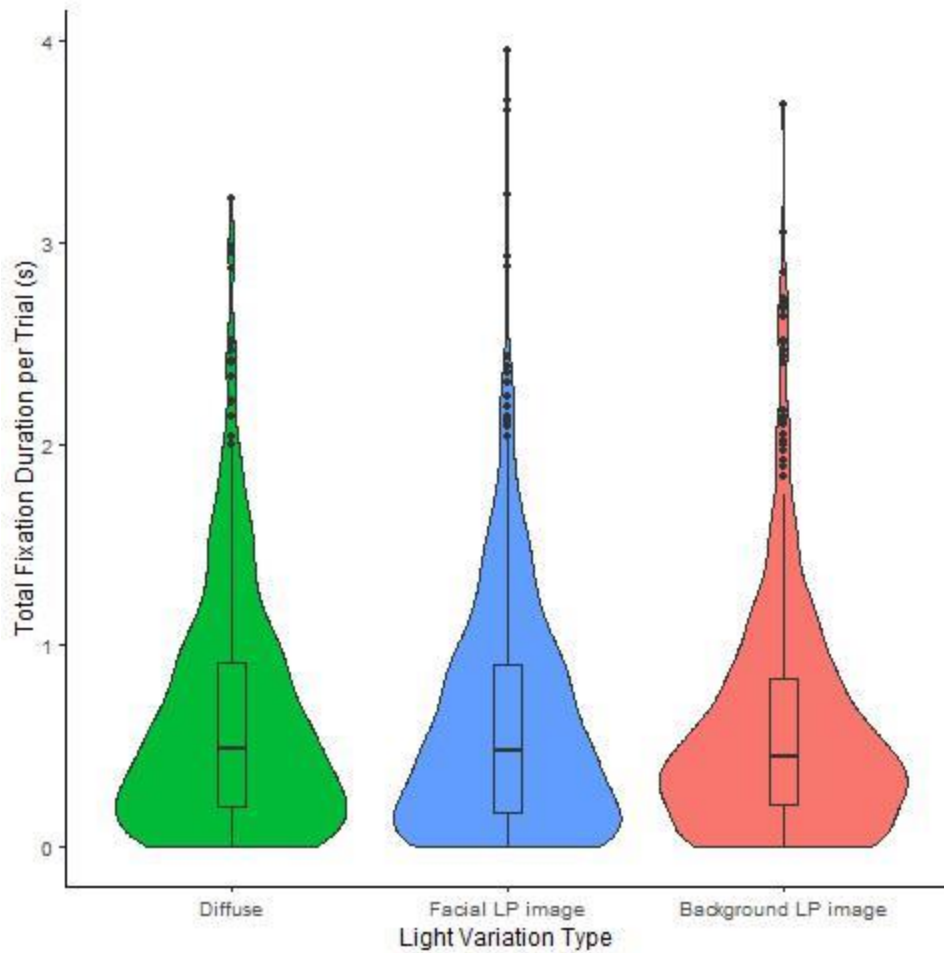


Figure 3.8 The total duration of spent fixating within the facial ROI region, compared across image types. There was no significant difference between light variation groups and total fixation duration in facial ROIs during the study phase of each image ($p > 0.05$).

Initially, there appeared to be no discernible advantage for any light condition in terms of memory accuracy (see Figure 3.9A) and a chi-square test of independence revealed that there was no significant relation between accuracy in the memory task and light condition type, $X^2(2, N = 20) = 2.0$, $p = 0.36$. However, there was a significant effect of light condition when segment type was considered. Light condition had a statistically significant effect when facial segments, $X^2(2, N = 20) = 9.0$, $p = 0.01$, and background segments, $X^2(2, N = 20) = 7.51$, $p = 0.023$, were tested in a 2AFC memory task (see Figure 3.9B and 3.9C). A post hoc test (calculated in R using the `chisq.posthoc.test()` function and the Bonferroni adjustment method) revealed that the background light patch image condition had a statistically significant effect on accuracy when tested on both the facial ($p = 0.017$) and background ROI ($p = 0.037$) segments. When all other segments (excluding facial and background segments) were

tested for accuracy, there was no significant effect of light condition on memory accuracy, $X^2 (2, N = 20) = 3.0$, $p = 0.22$ (see Figure 3.9D).

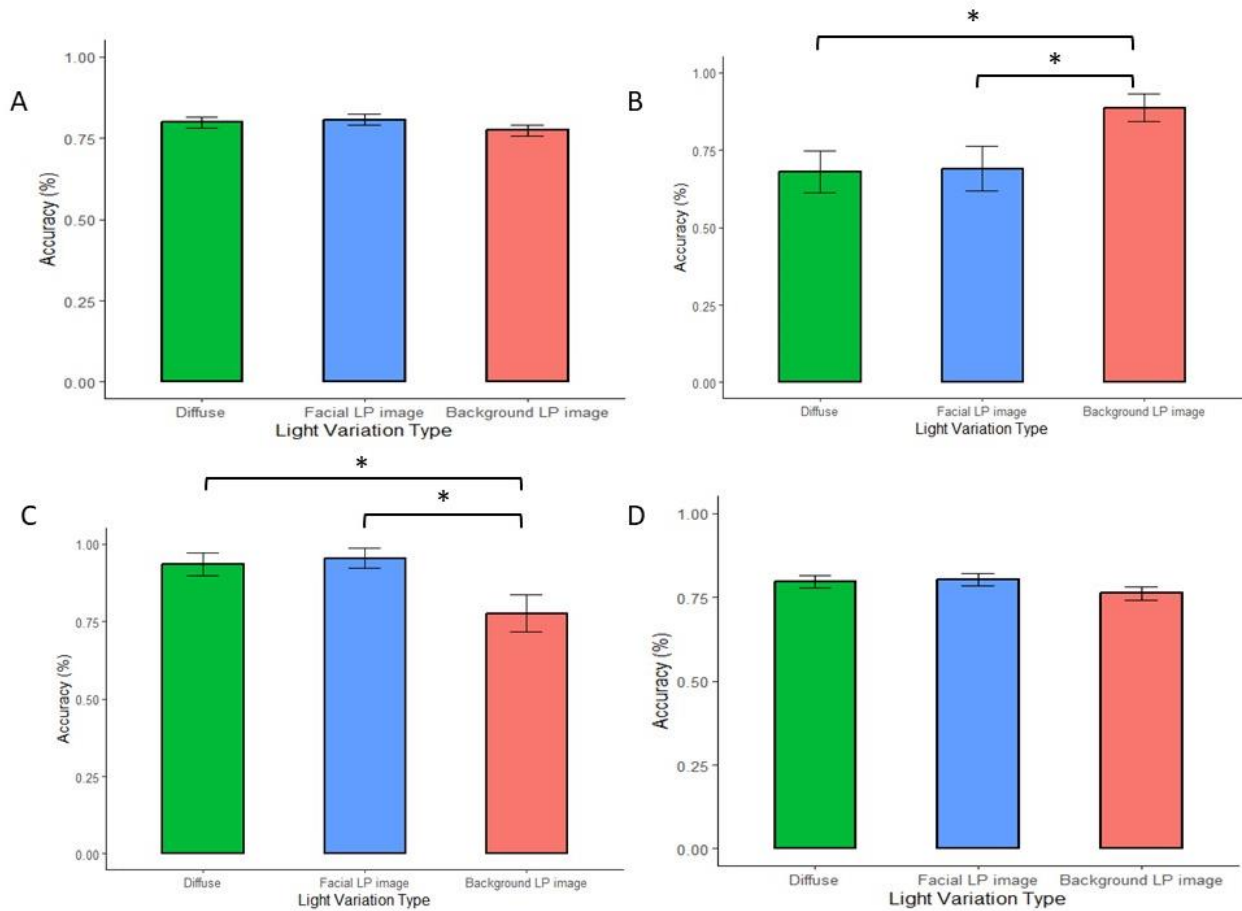


Figure 3.9 Percentage correct responses per light condition is plotted as a bar chart. In image A, memory accuracy for all segments is presented. In image B, accuracy for background segments per light condition is plotted, and in image C, memory accuracy for facial segments per light condition is shown. In image D, memory accuracy for all other segments (not including background and facial segments) per light condition is illustrated.

The relationship between light condition and memory was examined further by investigating response times in the memory task for each light variation type. A one-way ANOVA revealed that there was no significant effect of light variation condition on response time in the memory task (Figure 3.10), $P = 0.82$). When investigating response times for facial segments and background segments, there was also no significant effect of light condition ($p = 0.41$ and $p = 0.40$ respectively).

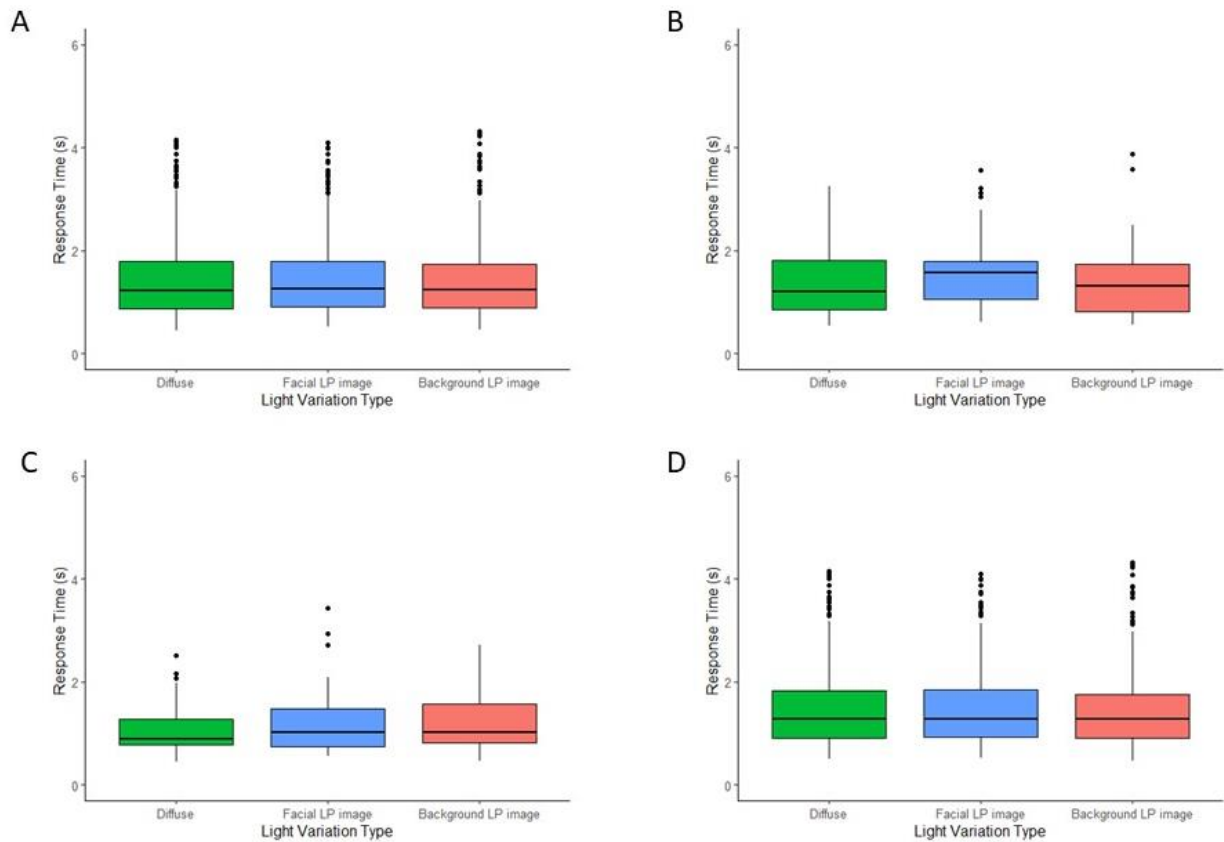


Figure 3.10 Box plots of response times (RTs) in the memory task per light condition. Image A) RTs for all image segments, image B) RTs for background segments, image C) RTs for facial segments and image D) RTs for all other segments (not including background and facial segments).

3.4 Discussion

Recent research into the distribution of attention when viewing complex scenes has demonstrated that locations with high contrasts in stimulus features like edge density and orientation are more strongly related to fixation distribution than other regions within the same scene with low visual saliency (Mannan et al., 1996). High fixation concentrations in regions with high luminance contrast have been observed in eye-tracking studies when participants view paintings, particularly in studies that use paintings created by artists that paint in the chiaroscuro style (Winter et al., 2022). Artworks painted in this style have clear contrasts between light and dark which is used to provide a dramatic and three-dimensional effect to the painting. However, to the best of our knowledge, no

studies have investigated how stimulus characteristics such as light can affect attention to features in translucent stimuli like stained-glass windows. Therefore, the goal of the current study was to determine whether light variation, which serves as a stimulus-driven (bottom-up) feature in stained-glass windows, can influence how one distributes their attention when viewing these complex stimuli. If an effect was present, we then aimed to investigate how changes in attention due to light variation may in turn change how people remember the features shown in these windows.

First, to validate that faces do attract attention in stained-glass windows, we analysed fixation distribution for each image visually by generating heatmap images. In these heatmaps, it is apparent that faces do preferentially attract the attention of participants, a result that was also observed in previous eye tracking studies using complex scene imagery (Cerf et al., 2009) or paintings (Fontoura et al., 2011; Yarus, 1967). As any portion of the window could potentially be shown to participants in the recognition phase of this experiment, facial stimuli were unrelated to the memory task and allocating attention to facial regions did not offer an advantage to participants. Nonetheless, this preferential focusing of attention to facial regions in stained-glass windows was still evident.

Light variation, in the form of differentially located patches of light, was shown to not affect this preference for facial features. Fixation number and the amount of time participants spent fixating in the facial ROI did not differ whether there was a light patch in the facial region, the background region or whether there was no light patch at all present. This result is intriguing, as the patch of light shining through the face in the 'Facial LP' image condition obscures any distinguishable facial features of the people present in these windows. Facial features such as eyes and mouths are obscured and therefore appear to not play a significant role in the attention-grabbing nature of faces. Instead, the early visual processing system may receive a signal from the scene's overall composition and gist that an important semantic content (a face) is likely to be present there.

Interestingly, placing a light patch in the facial region of a stained-glass window significantly increased fixation number and fixation duration for background regions compared to control images (diffuse lighting condition) and images with a light patch in that background region. It may appear that by essentially erasing the facial information in a window (reducing the contrast of facial features, i.e. eyes and mouths), the priority of allocating attention to the facial region may be reduced, and as a result, attention may be diverted to other areas of the stained-glass window in attempt to gain more information elsewhere. For example, if the facial features of a figure such as saint Patrick are distorted, participants may try to look for clues to the identity of the figure from other objects

depicted in the scene, for example a shamrock or a snake, which would be commonly known items associated with Saint Patrick.

Despite this, the removal of facial features via facially located light patch does not affect memory performance for facial segments, as the proportion of correct responses for these segments does not differ between images studied in the facial light patch condition and the diffuse condition. However, memory for facial segments is significantly reduced when a light patch is present in the background. This cannot be explained by an increase in fixation number to this background region, so therefore, a process other than overt attention must be responsible for this effect. This effect is observed again, as memory accuracy for background regions is similarly improved when a light patch is present in this background region. Therefore, it appears that when a light patch is placed in the segment region that participants will be evaluated on, memory accuracy for segments located in these background regions of stained-glass windows is significantly increased. These findings are with odds with the result that light patches in the background do not orient attention to these areas more than in control (diffuse lighting) conditions. While an accuracy effect is seen, response times are not influenced by light variation in a two-alternative forced choice memory test.

It is important to note that the small sample size used in this study was not sufficient to fully power our results based on our a priori power analysis. As a result, additional studies with larger samples are required to provide more comprehensive findings regarding light variation effects on attention and memory in the future. Another point of note is that in these stained-glass window stimuli, faces are either found in segment numbers two or five, and as a result, these segments are always centred in the image and the computer monitor.

In conclusion, we investigated the effects of light variation in the form of patches of light on attention distribution, memory accuracy, and response times using an eye tracking and 2-AFC memory task paradigm. Stained-glass windows are ideal stimuli candidates for such studies in bottom-up attentional orienting, particularly with regards to stimulus features such as luminance and colour, due to their unique transparency properties. In this study, we showed that light patches in stained-glass windows are unable to compete with face orienting. Despite this, light patches in background regions can increase accuracy in a memory test for the locations of the window that these patches occupy.

Chapter 4: The Contributions of Dynamic and Static Light Variation to Recognition Memory for Stained-Glass Windows.

4.1. Introduction

If you were to go on holiday to Paris and visit Chartres Cathedral in Paris, you might recount your experiences later to your friends and family by describing the stained-glass windows you viewed there. This account might include observations about the light shining through these windows and how it made you feel. Anecdotally, light is a feature of stained-glass windows that is mentioned when recounting experiences with stained-glass windows (Day, 1909). In Chapter 3, we demonstrated that light variation, in which one region of an image of a stained-glass window is more brightly lit than other regions, can affect the subsequent memory of the features within that region compared to regions that were not brightly lit. In this study, we were interested to see how recall for images of entire stained-glass windows are affected by different types of light variation, in which light varied in either a moving (dynamic) or fixed (static) manner.

Recognition memory is a subcategory of episodic memory, and recognition for visual images can be separated further into two different component processes: recollection and familiarity (Tulving, 1985). Recollection requires the high-confident recalling of details, while familiarity refers to a feeling that an item may have been seen before. Early research on recognition for complex visual images has mainly focused on how people remember static images. In a seminal study conducted by Standing in the 1970s, memory capacity for pictures was demonstrated to be “almost limitless” as participants were rapidly presented 600 images in succession and tested on their memory performance in a subsequent two alternative choice test. When tested immediately after the study phase, participants reached accuracies of up to 100%, a value that reduced down to 92% following a delay of one week (Standing, 1973). Equivalent results for this enormous memory capacity for images has been replicated by others using old/new recognition tests (Nickerson, 1965; Shepard, 1967). Despite this large capacity for remembering images, recognition for scenes has been shown to be reliant on presentation time. For example, in experiments using rapid serial visual presentation (RSVP), the limits of visual short-term memory can be tested to find that recognition memory for pictures is poor for images that are exposed for durations of less than 300 ms (Potter, 1976).

When predicting how light variation may influence how the memory of images of stained-glass window may be encoded and retrieved, scene-based information such as light and colour should be considered. Light variation may affect colour values while viewing, which has been shown to play a key role in recognition memory performance (Oliva & Schyns, 2000). Colour enhances visual recognition memory for natural scenes in comparison to scenes that are presented and tested in a black and white format (Brédart et al., 2014; Gegenfurtner & Rieger, 2000; Spence et al., 2005;

Wichmann et al., 2002). Wichmann and colleagues report that up to 40% of the variance observed in their study may be attributed to the luminance components of images, and later studies investigating the role of colour in recognition memory attempted to match the luminance across images to remove it as a diagnostic feature (Spence et al, 2005). Although investigations into the role of luminance in colour photographs on recognition memory in scene perception are sparse, luminance has been shown to have an effect on memory in tasks involving arrays. For example, Loftus (1985) showed that viewing images and digit arrays at high luminance improved memory compared to viewing the same stimuli at low luminance. Low luminance, according to Loftus, limits the amount of information that can be extracted from the image.

As shown above, recognition memory for complex visual stimuli has focused largely on how people remember static images. However, in the last ten years, there has been an increase in interest into how recognition memory for dynamic stimuli might differ from those that are presented in a static format. It has been shown in experiments involving arrays that onset of motion can attract attention (Abrams & Christ, 2003), and it has been shown in eye tracking studies that attention and memory are highly linked (for a review see Hannula, 2018). Dynamic information can improve recall for faces (Lander & Davies, 2007; O'Toole et al., 2002), however, researchers in this study were able to demonstrate this memory benefit only for moving stimuli in the encoding phase, and not the test phase of the experiment. In a previous study, better performance for dynamic stimuli compared to static stimuli was demonstrated by Goldstein et al (1982). However, in that study, dynamic stimuli were tested against dynamic stimuli, and static against static, so the effects of testing images in a mode different to that encoded were not tested. In that study, images in the study and test phases of the recognition memory test were not presented for the same amount of time (dynamic videos were presented for 10 minutes and static images for 5 seconds in the encoding stages). A later study resolved this issue by presenting and testing images for the 3 seconds each for both the dynamic and static encoding and testing conditions (Matthews et al., 2007). However, like the study conducted by Goldstein, the mode of presentation at study was the same as that at test. By counterbalancing the presentation mode of study and test stimuli, the congruency effect of encoding-retrieval similarity as suggested by Tulving (1983) was demonstrated with the 'dynamic superiority effect' by Buratto and colleagues (2009) and has been replicated many times since then (Candan et al., 2015; Ferguson et al., 2016).

In the following study, we were particularly interested in whether dynamic light variation across an image of a stained-glass window, in which shadows across the window would be moving in

a dynamic way (for example, the shadow of a tree blowing gently in the wind), would result in better encoding of the image of that window than encoding of images of windows presented with static light variation, i.e. without any light movement. Dynamic light variation was defined within this study as light and shadows that are moving and projected through a stained-glass window. We chose to create categories of dynamic light variation that were ecologically valid over a five second viewing period. For example, a rainstorm and clouds moving across the sky on a windy day can be viewed in a single period. On the other hand, the dipping of the sun at sunset requires a longer period of observation and would need to be time lapsed in order to view this phenomenon over a duration of five seconds. Static light variation was defined as light variation that does not move. To create our static light variation stimuli, we chose single frames from our videos of dynamic light variation. This allowed us to have similar patterns of light variation between the two groups. Based on the findings above, we proposed that a dynamic superiority effect would be observed when participants are asked to recall images of stained-glass windows that they previously encoded with dynamic light variations compared to those encoded with static light variations. This effect would be observed as better accuracy and/or shorter response times for images of windows previously encoded as dynamic over static light variations.

In this study, recognition memory for images of stained-glass windows was tested using a classic old/new recognition memory paradigm. This involved two stages: an encoding and test stage. During encoding, participants were presented with five second clips of stained-glass windows with dynamic or static light variations applied to them. Participants were asked to memorise these windows. Following encoding, participants then conducted a recognition memory test containing a mixture of previously viewed and novel window images. In this stage, all images of windows presented were of the same format, with diffuse lighting across the image. We refer to this mode of presentation as the 'diffuse state' for the rest of this chapter.

4.2. Methods

4.2.1 Participants

A minimum sample size of 30 participants was calculated for this study based on an a priori power analysis conducted in the power analysis program PANGAEA (Power ANalysis for GEneral Anova designs; <http://jakewestfall.org/pangea/>) and an effect size of 0.45.

A total of thirty-two participants (24 females, 8 males; $M_{age} = 35.38$ years, $SD = 10.10$) completed this study online using the recruitment platform Prolific (www.prolific.co). All participants were over the age of 18, resident in Ireland and naïve to the purpose of the study. All participants provided informed consent prior to conducting the experiment. Participants were compensated for their time at a rate of £9 per hour. On average, participants completed the study in 18 minutes 1 second ($SD = 6$ minutes 53 seconds). Informed consent was obtained at the beginning of the online experiment in accordance with the procedures that were approved by the Trinity College Dublin School of Psychology Research Ethics Committee [SPREC112022-04].

4.2.2 Materials

In Chapter 2, we created a database of 148 stained-glass window images that the sample of participants who were Irish residents rated as novel, had an even distribution of illumination, and were devoid of text, obstacles, and shadows. To select which of these images we would use in this study, we ordered these images in descending order of average distribution of brightness and selected the top 96 images in this list. A complete list of these image identification numbers can be found in Appendix D.

To create dynamic stimuli for use in this experiment, we first identified different variations of ecologically valid dynamic light patterns that could potentially be seen through a stained-glass window over the course of a five second viewing duration. The final list of light variation types included the following: rain falling behind a stained-glass window, a lightning storm, two birds flying in opposite directions sequentially behind a stained-glass window, a tree blowing in the wind and casting a shadow on the glass, clouds moving across the sky, and a firework show.

Before creating our dynamic and static stimuli, the 96 images of stained-glass windows were manually processed in Photoshop (Adobe Inc. (2019)). During this process, any region of an image that did not contain glass were masked using a black colour (see Figure 4.1). Some images of stained-glass windows had these regions as black before this process due to the images being taken in a dark setting. However, other images were taken in brightly lit spaces so the non-window architectural features present in the window were white. When we applied our manipulations later on, shadows would appear on these regions, as our masking function would identify them as windowpanes due to their low intensity luminance values. By masking these regions using the colour black, this issue was resolved. These 96 stimuli were then used as the test stimuli in the experiment.



Figure 4.1 Images A) before and B) after manipulation in Photoshop. Areas that did not contain glass were masked using a black colour in Photoshop. From the left, images are 132 and 025, respectively.

To create each example of lighting, a video capturing each type of the lightning categories identified above were sourced online on the websites Shutterstock and FILMSUPPLY. These videos were downloaded and imported into MATLAB (The MathWorks Inc. (2022)). The first 150 frames of these videos were kept after they were divided into individual frames in MATLAB. Each of these frames was changed into its black-and-white equivalent using a binary mask function in MATLAB (see Figure 4.2). This process of converting frames into binary mask images led to a loss of detail when creating the fireworks frames. As a result, fireworks frames were converted into images in grayscale instead.

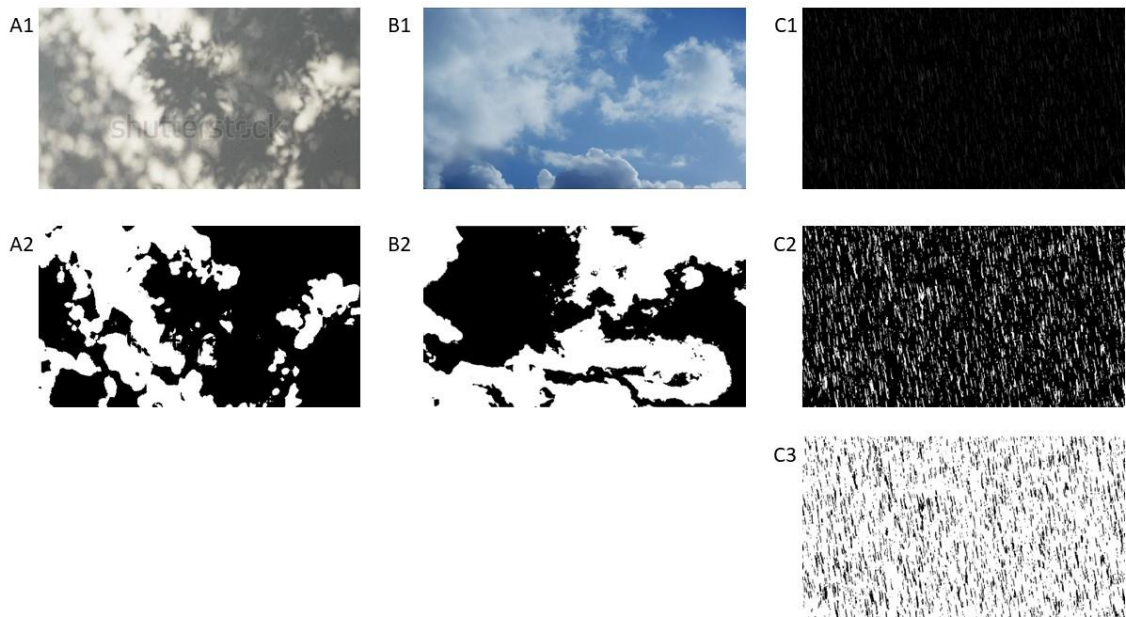


Figure 4.2 Examples of the frame creation process for three categories of lighting A) tree, B) cloud, and C) rain. Videos for each category of lighting were identified on the internet and condensed into frames (1). These frames are converted into black and white images (2). In the case of rain frames, the black and white frames were inverted (C3).

To apply these frames to our stained-glass window stimuli, 'light variation' frames and images of stained-glass windows were imported into Processing (<http://www.processing.org/>). A binary mask was applied to each stained-glass window image (binary threshold = 60) to create regions of interest (ROIs) identifying where panes of glass were located in each image. Black and white frames from the light variation videos were imported into the sketchpad and blurred. 'Light variation' frames were applied as a shadow mask only to the areas identified as panes of glass in each stained-glass window. The opacity and blur values used for the diverse types of light variations are shown in Appendix E.

Images of stained-glass windows were batch processed to generate 150 frames per stained-glass window image per lighting category. These frames were then imported into MATLAB and bound together to create 5 second video clips (30 frames per second) for each image and lighting category. As a result, we had a total of 576 videos (96 stained-glass windows x 6 type of lighting categories). To create the static image stimuli used in this experiment, frames were taken from each video. The same frame number was selected within lighting category (see Appendix E). For light categories that had continuous shadow movement (rain, tree, and cloud) the middle frame was selected, i.e., frame 075.

For video types with non-continuous light variation a frame that contained a notable shadow was selected. For example, we selected a frame from the bird stimuli that had a bird shadow located in the centre of the image. As window images have different sizes, if we chose a frame with the bird at the edge of the frame, the bird shadow would not have been visible in narrower images.

As a result, 13 versions of each of the 96 stained-glass window images were created for the experiment: one control version (no light variations applied), six dynamic light variation versions, and six static light variation versions (see Figure 4.3).



Figure 4.3 Examples of each lighting category used in this experiment are shown in each panel as follows: A) tree, B) bird, C) cloud, D) firework, E) lightning, and F) rain. Stained-glass window image identification numbers are A) 131, B) 013, C) 160, D) 017, E) 113, and F) 003.

4.2.3 Design

Viewers took part in one of four experimental conditions (variations in the presentation of dynamic or static stimuli study-test blocks). The different experimental conditions are illustrated in

Table 4.1. Eight participants were randomly allocated to take part in each of the four experimental conditions.

Table 4.1 The order in which blocks of images are encoded (dynamic vs static) is counterbalanced in this study.

Experimental condition	Block presentation order
A	Dynamic-dynamic-static-static
B	Dynamic-static-dynamic-static
C	Static-static-dynamic-dynamic
D	Static-dynamic-static-dynamic

At the beginning of every experiment, a list of the 96 images of stained-glass window stimuli was divided equally into four lists containing 24 images of stained-glass window images. These four lists of images were assigned to one of the four experimental blocks. Half of these 24 windows were allocated to appear in the encoding phase of each block. Two of the blocks presented these images in the dynamic condition. The other two blocks showed these images in the static condition. All 24 images appeared in the control condition (diffuse lighting) in the test phase of each block. No image appeared in more than one experimental block.

In the encoding phase of each block, every lighting category was shown twice (6 x 2). The presentation order of each lighting category was counterbalanced blocks and across participants.

4.2.4 Procedure

Before starting, participants were given detailed instructions about what to expect in the form of a participant information sheet and were told to respond as quickly and as accurately as possible to each image during the test phase. Participants were informed about how their data would be handled once the experiment was launched online and given the chance to give their consent. The experiment was terminated if consent was not collected. We required that the study be completed on a desktop computer as opposed to a tablet or smartphone so that the images of stained-glass windows would be viewed on a larger screen. This requirement was enforced by a feature that prevented participants from moving on to the next part of the experiment until they pressed the spacebar. Before starting the main experiment, participants completed a practice block consisting of a study phase and a test phase. Participants were asked to memorise 4 images of paintings for 5

seconds each. Following this, participants were tested on 8 pictures of paintings, half of which had appeared in the study phase and half of which were novel. Participants were given feedback in this practice block and upon completion, they then continued onto the main experiment. Feedback was not provided in the main experiment.

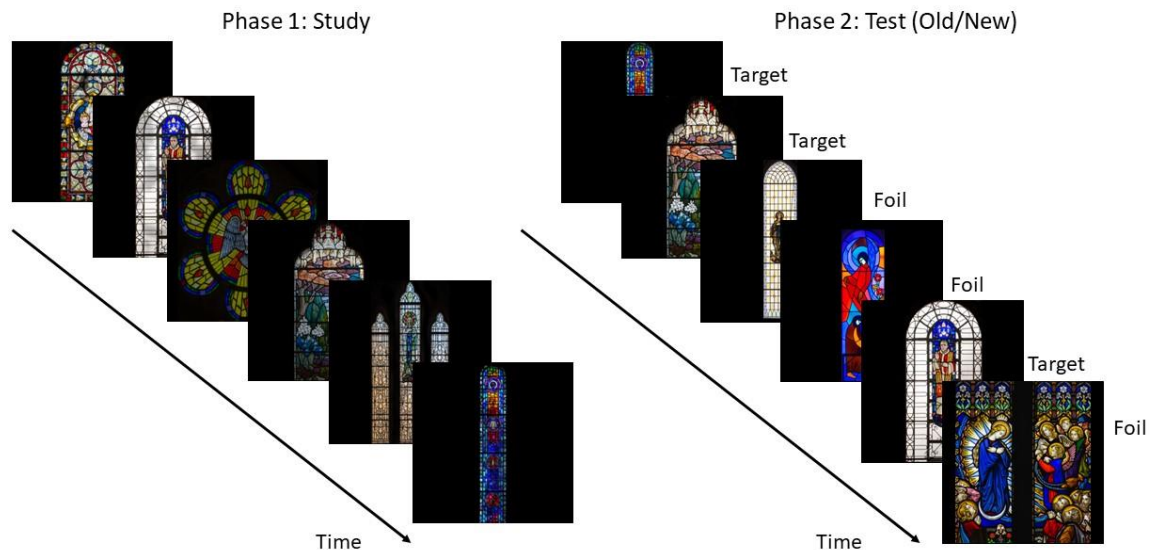


Figure 4.4 An example of a study (encoding)-test block in this study. In this Figure, only 6 images are shown in the study phase and test phases. In the actual experiment, 12 images were presented in the study phase, and 24 images were tested in the test phase. In the encoding phase, images are presented with static or dynamic light variations applied to them (depending on what block the participant took part in) for 5 seconds. Test stimuli are presented in their diffuse condition in all blocks. Not shown: a 500 ms blank screen and 500 ms screen with a fixation cross appeared before the presentation of each image in both the study and test phases.

In the main experiment, participants were asked to complete 4 blocks of trials. Half of these blocks presented dynamic stimuli in the encoding phase, and the other half presented static stimuli in their encoding phase. The order in which participants completed these blocks was counterbalanced between participants (see Table 4.1). In the encoding phase of each block, participants were shown 12 images or videos of stained-glass windows in either the dynamic or static mode for 5 seconds. A blank screen, and a fixation cross for 500 ms each preceded the presentation of each study image/video. Once all 12 images/videos had been shown a countdown of 5 seconds appeared on the screen, after

which, the test phase of the block would begin. In this phase, participants viewed 24 images of stained-glass windows without *any* light variations applied to them. Again, a 500 ms blank screen, and a subsequent 500 ms fixation cross preceded the presentation of each image. Participants pressed the “A” key on the keyboard to indicate if they had previously seen the stained-glass window illustrated in the image in the study phase of the block. If the participant perceived the stained-glass window depicted in the image as novel, they pressed the “L” key. Participants had 5 seconds to respond to these images before a “Too slow!” message would appear on the screen. Participants were instructed to answer as quickly and as accurately as possible. A 30 second inter-block interval separated the experimental blocks. A sample block of trials is illustrated in Figure 4.4.

After the study was completed, participants received debriefing materials outlining the goals and methods of the investigation. Overall, the experiment took an average of approximately 18 minutes (SD = 7 minutes) for each participant to complete.

4.2.5 Analysis

A CSV (comma separated value) file was generated for each participant through Pavlovia (<https://pavlovia.org/>) and recorded the type of stimuli (static or dynamic) and the light variation type (rain, lighting, cloud, tree, firework or bird) presented in each trial. Experimental condition, participants key responses (old or new), correct responses and response times per trial were also recorded. Data were imported into R for analysis.

4.3 Results

Response times

Mean response time (RT) in the test phase for correct responses for each encoding condition was calculated using R. On average, participants correctly identified images that had been shown in the dynamic condition within 1.21 seconds (SD = 0.51), while it took longer on average for participants to correctly identify images that had been encoded in the static condition (M = 1.34 seconds, SD = 0.68 seconds). A two sample t-test revealed this difference in mean response time between the two encoding conditions to be significant, $t(951) = -3.38$, $p < 0.001$. Stimuli encoded in the dynamic mode in the study phase are recalled quicker than those encoded in the static condition (see Figure 4.5). A two-way ANOVA was performed to analyse the effect of encoding condition and lighting category on response time for correctly identified targets. This revealed that there was not a statistically significant

interaction between the effects of encoding condition and lighting category ($F(1, 6) = 0.88$, $p = .49$), as illustrated in Figure 4.6.

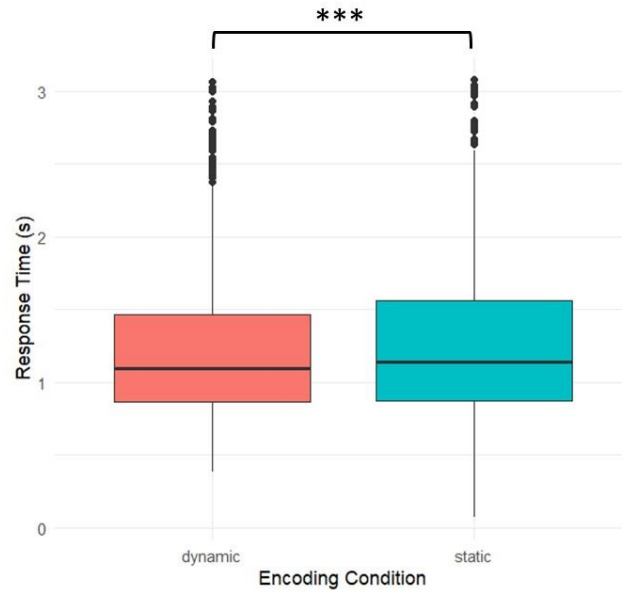


Figure 4.5 Response times in the test phase for images encoded in either the dynamic or static condition during the study phase of the experiment is represented within a boxplot figure. Within each box, horizontal black lines denote median values. The median response time for images encoded in the dynamic condition was 1.06 seconds, and the median response time for images encoded in the static condition was 1.13 seconds. The asterix denote that a significant difference between mean response time for each encoding category is observed ($p < .001$).

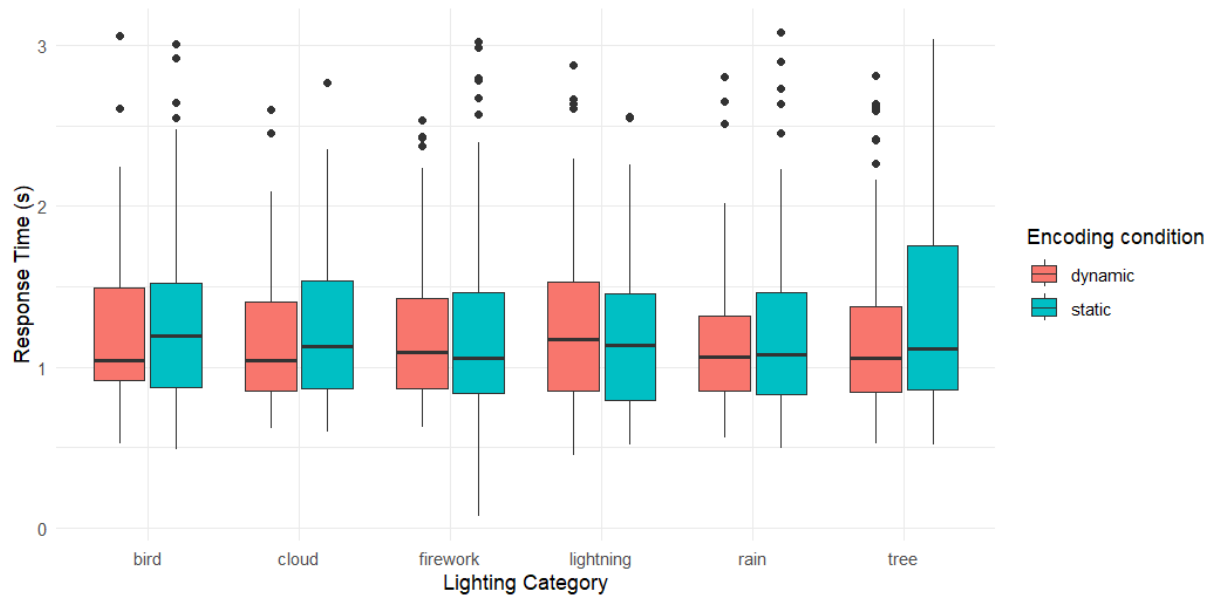


Figure 4.6 Response time per trial during the test phase of the experiment per lighting category. Red boxplots indicate response time for images studied in the dynamic condition and blue boxplots represent response time for images studied in the static condition. Figure does not include response times for incorrect trials.

Response accuracy

On average, participants correctly identified targets in the test phase of the experiment 71.22% of the time when images were encoded in the dynamic condition (SD = 45.30%), and 67.92% of the time when encoded in the static condition (SD = 47.08%), see Figure 4.7. We performed a Pearson's Chi-Square test to analyse the effect of encoding condition (dynamic or static) on recall accuracy in this experiment. Chi-square test was chosen because the outcome variable for memory performance in this study was binary (0 or 1). According to this analysis, the encoding condition did not have a significant impact on the likelihood of correct answers $\chi^2(1, N = 32) = 3.12, p = .08$.

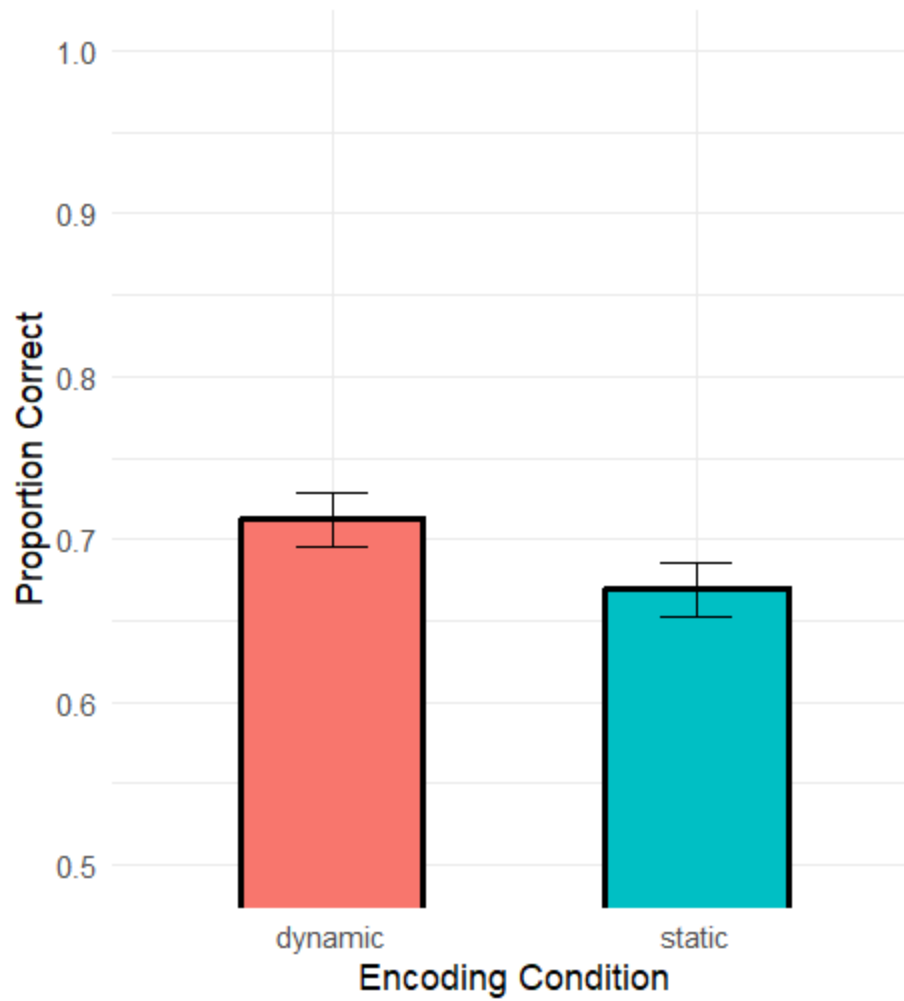


Figure 4.7 Results from the recognition memory task. The correct proportion of responses per encoding condition is shown. Error bars illustrate the standard error for each condition.

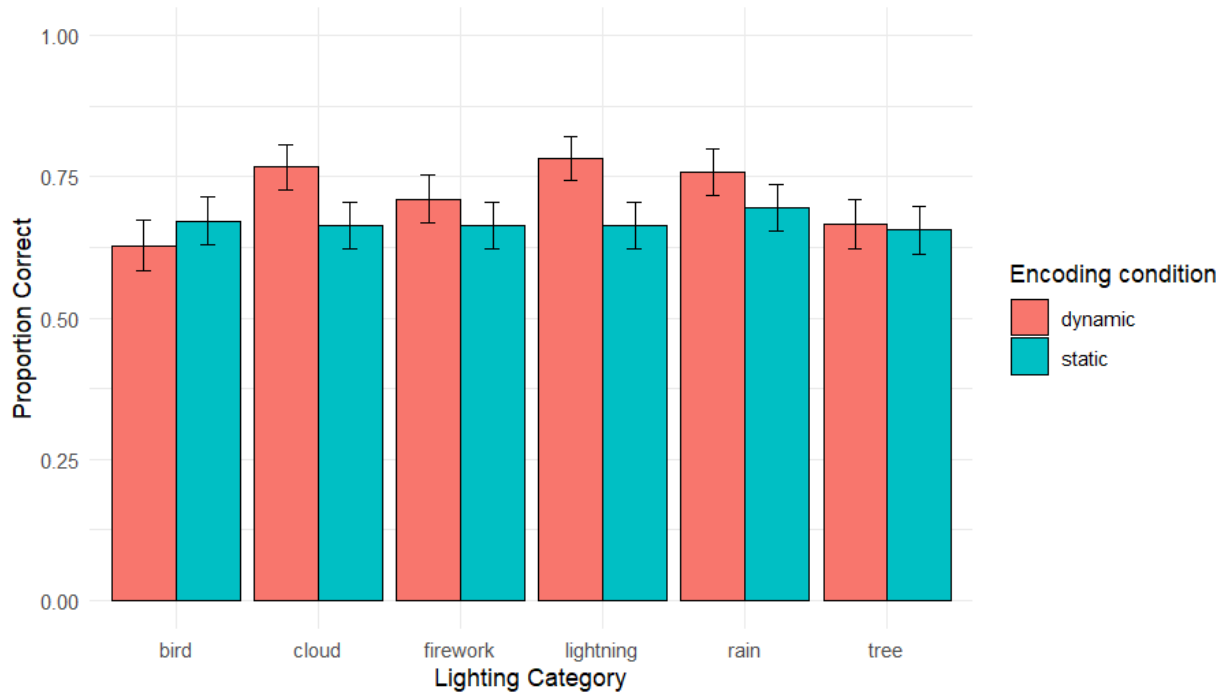


Figure 4.8 Proportion of correct responses per lighting category (bird, cloud, firework, lightning, rain, tree). Proportion of correct responses per encoding condition, dynamic or static, are also shown. Error bars illustrate the standard error for each condition.

4.4 Discussion

The findings from this study demonstrate a benefit on the speed of recognition memory for images of stained-glass windows that are presented with dynamic light variations in the encoding phase of a memory test, compared to equivalent images of stained-glass windows with static light variations applied to them. These results are demonstrated by a faster recall for images that were studied with dynamic lighting than those learned with static lighting. These results were consistent with earlier studies on scene learning (Buratto et al., 2009; Goldstein et al., 1982; Matthews et al., 2007) that moving images are better remembered than static ones. However, in these studies, better recognition for dynamic images is demonstrated by an increase in memory accuracy for target images compared to those for static images. In our study, increased accuracy was not observed, however, shorter response times were identified for participants correctly identifying stimuli that had been encoded in the dynamic condition than in the static condition.

In this study, we tested short term memory for our stimuli as we asked participants to partake in the test part of this study immediately after each study block. This practice is typical of other studies

investigating recall for dynamic and static stimuli (Candan et al., 2015). However, this dynamic superiority effect has been observed up to a period of 3 days (Buratto et al., 2009) and even up to a month post study (Matthews et al., 2007), indicating that movement information may also aid the encoding of visual long-term memory.

Why might images of stained-glass windows with dynamic lighting be remembered faster than those with static lighting? Candan and colleagues (2015) suggested that moving stimuli might provide a memory boost due to increased attention. It has been illustrated in an array study that motion onset can attract attention (Abrams & Christ, 2003) which may facilitate better encoding and retrieval due to contextual facilitation and binding (Biederman, 1972). Buratto and colleagues (2009) proposed that dynamic stimuli may aid better encoding and retrieval due to these stimuli containing more information in the same viewing period than equivalent static stimuli. More information may lead to there being a greater number of cues available to aid retrieval. Buratto and colleagues also proposed that dynamic stimuli may help keep participants more engaged in the task which should aid learning.

Matthews and colleagues (2010) tested this theory that the dynamic superiority effect may be attributed to the fact that moving stimuli attract more attention by dividing participant's attention during the encoding task. Participants were presented with black and white video clips or frames for periods of three seconds. During the encoding stage, participants were assigned either to the 'full attention' or 'divided attention' condition. In the divided attention condition, participants had to perform an auditory task while memorising the dynamic and static stimuli. After a 24-hour period, it was shown that the secondary task was sufficient to draw attention away from the encoding task, as participants in this condition had lowered overall performance. However, the interaction between attention and study mode was not significant. This illustrated that dividing attention at study does not eliminate the dynamic superiority effect, suggesting that memory boost for dynamic images is not attributed to higher attention and participant engagement during study.

In this study, we did not test for congruency effects, i.e., whether there is an increase in recognition performance if images are presented in the same mode at test and at study. Participants view dynamic and static stimuli in the study phase only, and in the test phase, recognition memory is tested with stimuli without any light variations applied to them. Other studies that have investigated the dynamic superiority effect in complex visual stimuli had participants memorise and recognise images in both dynamic and static modes in order to investigate whether presenting stimuli in the same mode that they were encoded in aids recognition (Buratto et al, 2009; Matthews et al., 2010).

In this study, we were interested in memory for images of windows, and not for the lighting conditions applied to them. We found that the type of lighting category applied to each window did not contribute to the better recall associated with dynamic stimuli.

Overall, we did not find a dynamic superiority effect when looking at recognition accuracy between the two encoding conditions. Overall, participants correctly recognised 75% of the test images. This level of recognition is consistent with research examining recognition performance for static scenes (Konkle et al., 2010). This performance is also consistent with our findings from Chapter 3, in which participants were asked to identify target segments in a two-alternative choice task from study images with static light patches applied to them. However, in the experiment reported in this Chapter, foils were matched to target images for content, style, and colour.

In conclusion, the results of this experiment suggest that images of stained-glass windows with dynamic light variation were better recognised than images of stained-glass windows with fixed light variation, and this advantage for moving light is shown by shorter response times when responding in the test phase. Whether the makers of stained-glass windows have an intuition of this memory effect is unknown, but it might be suggested that there may be an opportunity for stained-glass artists to take advantage of this fact in the future to create more engaging and memorable pieces of art.

Chapter 5: General Discussion

The use of stained-glass windows as artistic and architectural components dates back hundreds of years and across numerous cultures. Stained-glass windows have historically been used in Ireland to decorate places of worship, particularly in Catholic churches. In the past, stained-glass windows served the purpose of illustrating stories depicted in the bible to illiterate churchgoers. Stained-glass windows serve the added purpose of illuminating sacred spaces with vibrant and colourful lights in addition to their excellent narrative potential. Depending on the time of day and the cyclical nature of the seasons, the light that enters a space through stained-glass windows can give it a dynamic life. Light is an important symbol in many religions, which can signify spirituality, purity, and the afterlife. One of the first individuals to use stained-glass windows to illuminate a cathedral was Abbot Suger, who was tasked with renovating the cathedral of St. Denis in 1137. Suger believed that the light shining through these windows would have been comparable to the light of God, supporting the religious imagery and symbolism of the medium (Ramos, 2014).

The illumination coming through stained-glass windows and how this lighting made them feel are commonly emphasized when individuals describe their experiences after viewing stained glass windows (Day, 1909). In this thesis, we investigated how the interaction between light and stained-glass windows might affect how attention is distributed and memory performance for the observed features depicted in these windows. William James (1890) noted that the features of the visual stimulus as well as the viewer's expectations and intentions might affect how his or her attention is allocated when seeing visual stimuli. This view is supported by current theories of attention, which contend that attention is divided between bottom-up (stimulus-driven) and top-down (goal-directed) influences (Egeth & Yantis, 1997). According to research by Parkhurst and colleagues (2002), attention and gaze are distributed according to how much one stimulus stands out from others. They discovered a correlation between attention allocation and values of a visual stimulus that incorporate colour, light intensity, and orientation. This connection is particularly evident in the initial fixations made immediately after seeing a stimulus. In Chapter 3, we aimed to investigate this link between fixation density and duration, and light location within a stained-glass window. Attention and memory have been shown to be connected in a bi-directional manner (Hannula, 2018) and we explored how this relationship is influenced by light variation in this chapter. In Chapter 4, we study how recognition memory is affected by the encoding condition of an image of a stained-glass window; specifically, whether the lighting conditions of this window are dynamic or static.

5.1 Summary of Results.

In Chapter 2 the stimuli chosen for use in studies investigating the role of light variation on attention and memory when viewing stained-glass windows were determined. Specifically, images of stained-glass windows that participants were familiar with and that possessed an uneven distribution of lighting were removed from our previous database of images of stained-glass windows that had been captured in Dublin, Ireland. Participants had varying levels of familiarity with the content depicted in the stained-glass windows that they were asked to rate, and as such, familiarity to the content depicted in these windows was not a factor that was taken into consideration when narrowing down our database.

In Chapter 3, the role of light variation was investigated to examine how it influences the allocation of attention when viewing stained-glass windows. Images of stained-glass windows could be presented in their original form, with no lighting manipulations applied to them, also referred to as their 'diffuse' condition. Additionally, images of stained-glass windows could either be presented with a light patch in the facial region or in a non-facial region. Participants viewed all of our stained-glass window images in all of these three different light variation conditions. Eye-movements to facial and background regions were recorded during the viewing of these images. The results suggested that facial regions in stained-glass windows were extremely attention grabbing, as heatmaps representing the distribution of fixations during image presentation revealed that participants fixated on the facial region of the stained-glass window images for most of the viewing period. Attention has been shown to be preferentially directed to faces than to other objects in complex scenes (Ro et al., 2000) and in paintings (Winter et al., 2022). In this Chapter, we replicate these findings using an artform that has not been the subject of psychophysical analysis before, and we find that light variation is not sufficient to compete with this facial capture effect. When a patch of light is placed on a non-facial region of a stained-glass window image, the number of fixations that this region attracts does not differ irrespective of whether a light patch is present in this region or not. However, if there is a patch of light in the facial region, participants will fixate more on the background. One reason for this outcome may be that the light patch removes the contrast present in the facial region, and as a result, the facial features can no longer be identified. As such, participants are forced to look elsewhere for information about the scene.

In the experiment reported in Chapter 3, participants' memory for features depicted in stained-glass windows was examined in a two alternative forced choice memory test immediately after the presentation of each study window. This section of the experiment set out to specifically investigate whether or not the presence of light patches in images of stained-glass windows could influence memory performance for those illuminated regions. When we compared memory performance for these regions across lighting conditions, we found that light patches in stained-glass windows in non-facial areas significantly improved memory recall for these areas. In addition, memory for facial regions significantly worsened when light patches were present in the background.

In Chapter 4, the role of light in the recognition of images of stained-glass windows was addressed across two different encoding conditions: dynamic and static light variation. The greater part of research concerning recognition memory for moving and static stimuli has relied predominantly on research involving imagery of complex scenes (Matthews et al., 2007; Buratto et al., 2009; Candan et al., 2015). In this experiment, we presented participants with images of stained-glass windows with lighting fixed on the window, or the same lighting patterns moving during viewing. Participants recall for each window was then tested in a subsequent yes/no recognition task. The results from this experiment showed that memory recall for images of stained-glass windows is faster for images of stained-glass windows that were encoded with moving light compared to those encoded with static lighting.

5.2 Practical Implications of Findings.

In both Chapters 3 and 4 we discovered that while light variation does not influence the deployment of attention when viewing stained-glass windows, however, light variation does have a significant influence on how entire, and parts of, stained-glass windows are recognised at a later stage. In Chapter 3, light patches in non-facial regions of stained-glass windows were shown to improve memory for these regions compared to when participants are shown the same stained-glass window with a light patch in a facial region, or in no region at all. Participants revealed a high accuracy for recognising images of stained-glass windows in this experiment, however, in Chapter 4 we showed that recognition memory for stained-glass windows is further improved by presenting participants with images of stained-glass windows with *dynamic* lighting applied to them in the encoding stage of our memory experiment. From these results we can propose that the movement of objects behind stained-glass windows, for example trees and birds, have the potential to increase the memorability

of these windows, and should not be viewed as liabilities. In addition, it has become an increasingly more popular practice to illuminate stained-glass windows artificially with light boxes due to overcrowding of city regions as neighbouring buildings reduce the amount of light able to permeate these windows. For stained-glass windows that are artificially illuminated, for example by light boxes, there may be an opportunity to increase their memorability by artificially simulating dynamic light variations behind them.

5.3 Future directions

In the experiments detailed in this thesis, we manipulated lighting conditions in stained-glass windows virtually, by taking images of these artworks and manipulating RGB colour and intensity values in programs such as Photoshop and Processing. Measuring attention and memory responses to the original representations of these stained-glass windows would have been preferable, however, due to their size and placement, stained-glass windows are challenging to analyse using controlled light (Thanikachalam et al., 2016). It has been shown that cognitive and emotional responses towards artworks presented as digital representations on a computer screen differ compared to those as seen in the original format (Reymond et al., 2020). This effect may be due to image quality, resolution, and format. Reymond and colleagues (2020) make the argument that one of the driving factors of this lower aesthetic appreciation for images of artworks is changes in the representation of colour between these images and the original art piece. Despite this, the majority of research examining the eye movement patterns and memory performance of individuals seeing paintings and complex scenes have been carried out in a lab using visuals displayed on a computer screen. This method allows full control of the properties of the images, for example the size, colour, and in our case, light. It also allows researchers control of the number of images viewed, the order in which these images are shown, and the timing of image presentation. These aspects cannot be controlled in the native environment in which stained-glass windows typically reside. Unlike paintings which can be grouped together in a gallery setting and studied in their original format (Reitstätter et al., 2020; Walker et al., 2017), stained-glass windows cannot be studied in this way due to the fact that these windows are permanent structures and are unlikely to be moved from their original sites. We propose that in order to overcome some of the difficulties mentioned above, an alternative method to investigate the role of light variation on the attending to and memory of stained-glass windows might be to present these images in virtual reality (VR). In this format, the physical properties of these windows would be able

to be manipulated in a controlled manner, however, these windows would be able to be viewed in a more natural environment. Thanikachalam and colleagues (2016) have developed an interactive model to virtually relight stained-glass under dynamic light illuminations that could be adapted for this purpose in potential future studies.

Another possible direction for this research could include the investigation of light variation in stained-glass windows on long term representations of these windows in memory. In other studies investigating the dynamic superiority effect, this effect was shown to remain for up to periods as long as one month (Matthews et al, 2010) after exposure to complex images. The stimuli used in this experiment only consisted of clips from movies that were in black and white. It would be interesting if we could recreate these finding using stimuli that differ both in medium and with colour.

5.4 Conclusion

The experiments conducted as outlined in this thesis have contributed to a greater understanding of how the interaction of light with stained-glass windows can influence cognitive responses to these artworks, specifically for the processes of attention and memory. These findings should improve our comprehension of how light variation transmitted by stained glass affects perception, but also may alter perceptions of stained-glass and its empirical investigation among those researching the psychology and history of religious art. Furthermore, we anticipate that the findings of our study will raise awareness of the value of light variation among artists who continue to create stained-glass windows for religious settings, or artists in other mediums as well. Future applications for the results of this study might include improvements in art and design as the influence of light on attentional and memory mechanisms on the viewers of artworks is explored.

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Appendix A - Letters of approval from Research Ethics Committee



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin

Ollscoil Átha Cliath | The University of Dublin

F.A.O. Kate Nevin

Approval ID: SPREC112022-04

School of Psychology Research Ethics Committee

19th December 2022

Dear Kate,

The School of Psychology Research Ethics Committee has reviewed your application entitled "Through a glass brightly: Light Variation through Religious Stained Glass and its effect on Attention and Memory", and I am pleased to inform you that it was approved.

Please note that you will be required to submit a completed **Project Annual Report Form** on each anniversary of this approval, until such time as the research is complete and the thesis is submitted. The form is available for download from the Ethics section of the School website.

Adverse events associated with the conduct of this research must be reported immediately to the Chair of the Ethics Committee.

Yours sincerely,

Richard Carson
Chair,
School of Psychology Research Ethics Committee

Scoil na Siceolaíochta
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TCD Security: 01 896 1317

Any incidents such as those described below **must** be reported to the Head of School and to the Ethics Committee

SCENARIO 1: Participant becomes distressed without apparent cause. No risk of harm is evident to researcher.

The lab environment may be intimidating. During testing, a participant becomes notably distressed or uncomfortable.

Response:

- End data collection.
- Ask how the participant is feeling to identify problem: e.g., *are you feeling overwhelmed/claustraphobic/uncomfortable etc?*
- Remind the participant of their right to end data collection and/or withdraw from the study at any time.
- Offer a break. Offer water. Ask if they'd like to step outside. Ask if they have any strategies (e.g., mindfulness) that help when they are feeling distressed.
- After the session has ended, inform study PI. Review study procedures to understand the source of the distress and to identify if recurrence can be prevented.

SCENARIO 2: Participant discloses a history of self-harm or current plans to self-harm

It is possible a participant will disclose information that suggests that they are at risk through their own behaviour. Here, assess the risk level and decide an appropriate response.

Risk assessment is informed by three pieces of evidence. Any one of these alone may be sufficient to prompt a response.

1. Excessive concern of experimenter.
 - *Does the participant's behaviour, words, or actions worry you?*
 - *Have they indicated (e.g., on a clinical assessment) that they are experiencing high levels of distress and/or have a suicide plan?*
2. Immediacy of risk.
 - Do the participant's words or actions suggest that they are at immediate risk – e.g., suicide plan is ready.
3. Availability of support services – what is the answer to the following questions?

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- *"Are you in counselling?"*
 - *"Are you in contact with a mental health service?"*
 - *"Does anyone else know about these feelings?"*
4. Is the participant a TCD student or someone from outside the College?

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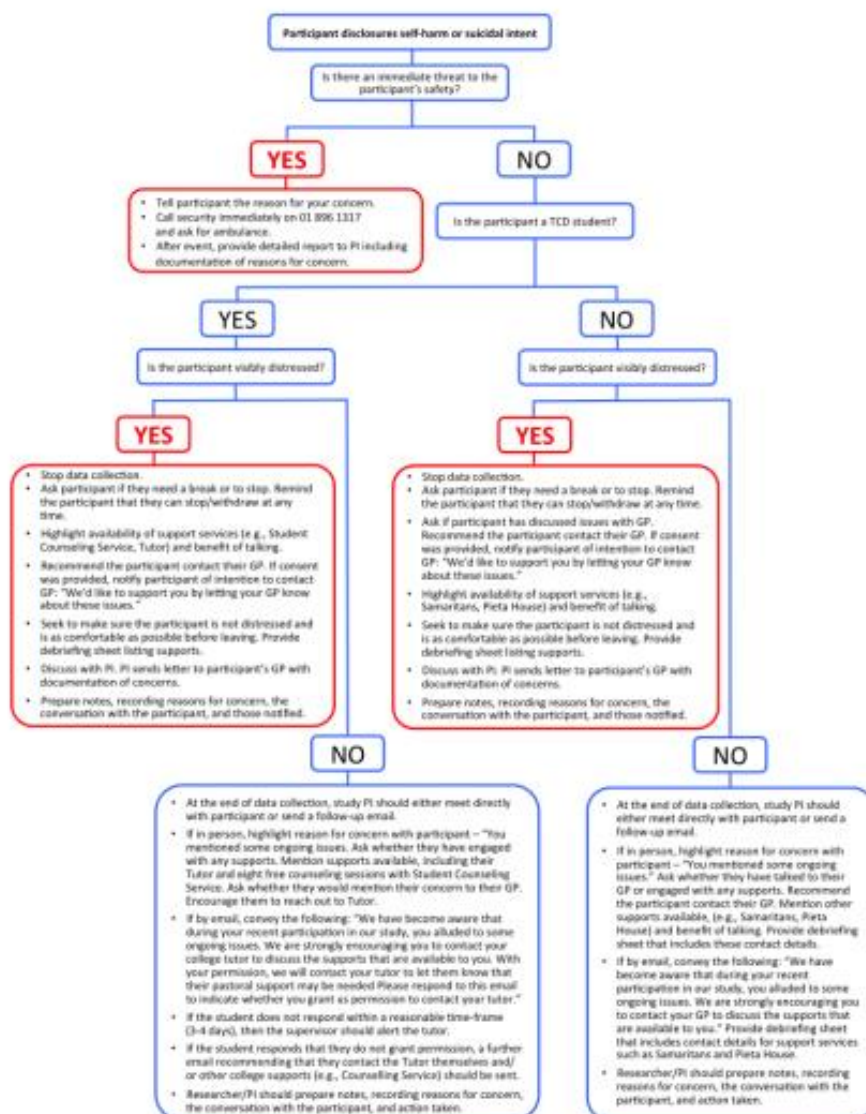
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Appendix B - Average scores for each window for all rating study statements.

Image ID for thesis	Original Image Name	Evenness of Brightness Distribution	Window Familiarity	Story/character Familiarity	Colour complexity	Pane complexity	Scale
"001"	20210129-DSC_4224	5.70	2.70	4.10	5.10	5.20	5.10
"002"	20210129-DSC_4235	5.30	2.40	4.10	5.10	5.40	3.40
"003"	20210201-DSC_4294	4.90	1.70	2.80	3.80	4.10	3.70
"004"	20210201-DSC_4337	3.60	1.40	2.10	6.00	6.70	5.90
"005"	20210201-DSC_4345	5.00	3.00	2.70	6.40	6.60	5.30
"006"	20210201-DSC_4355	5.90	1.80	2.60	6.60	6.30	5.90
"007"	20210201-DSC_4364	4.56	2.20	2.70	6.70	6.90	6.20
"008"	20210202-DSC_4507	4.90	3.00	5.60	5.50	5.60	5.60
"009"	20210204-DSC_4624	1.90	1.60	1.30	4.90	5.30	4.40
"010"	20210204-DSC_4632	4.40	2.80	4.10	5.10	5.70	4.50
"011"	20210204-DSC_4635	4.50	2.80	3.00	4.80	5.90	4.60
"012"	20210204-DSC_4637	5.00	3.20	3.90	5.20	5.00	5.40
"013"	20210204-DSC_4644	5.10	2.00	3.20	5.60	5.90	5.30

"014"	20210204-DSC_4649	5.00	1.80	3.00	5.30	6.00	5.20
"015"	20210204-DSC_4653	5.00	2.80	3.70	6.10	6.50	6.20
"016"	20210204-DSC_4674	4.80	2.50	2.10	3.60	3.40	2.30
"017"	20210204-DSC_4674	4.90	2.70	3.40	3.70	3.70	4.00
"018"	20210204-DSC_4676	4.50	1.90	2.70	3.90	4.20	4.50
"019"	20210204-DSC_4677	3.70	1.90	2.60	3.70	4.20	4.40
"020"	20210204-DSC_4678	3.70	2.20	2.60	3.80	4.40	4.40
"021"	20210204-DSC_4679	4.70	1.80	2.80	2.80	3.80	3.80
"022"	20210205-DSC_4819	4.10	3.30	4.30	5.90	6.10	5.60
"023"	20210205-DSC_4842	5.80	2.60	6.10	5.10	5.70	5.50
"024"	20210212-DSC_4855	5.40	2.10	3.60	3.40	5.60	5.40
"025"	20210212-DSC_4882	5.30	2.30	2.70	5.00	5.00	4.00
"026"	20210212-DSC_4911	5.00	2.67	2.90	5.30	4.70	4.40
"027"	20210212-DSC_4911	4.40	2.20	3.00	4.20	4.50	4.90
"028"	20210212-DSC_4962-2	5.11	2.60	4.60	5.60	5.80	4.60
"029"	20210212-DSC_4964	5.70	1.60	5.30	5.80	5.90	5.10

"030"	20210212- DSC_4966	5.80	2.70	5.70	6.30	6.60	5.00
"031"	20210212- DSC_5002	4.70	1.40	1.30	6.50	5.90	5.60
"032"	20210212- DSC_5003	4.20	3.00	3.60	6.70	6.40	5.50
"033"	20210212- DSC_5005	4.90	2.00	2.70	6.70	6.60	5.00
"034"	20210212- DSC_5006	4.90	2.80	2.70	5.80	6.40	6.40
"035"	20210215- DSC_5113	5.70	2.10	4.80	6.00	5.70	3.80
"036"	20210215- DSC_5199	4.80	3.20	2.80	5.20	4.60	5.10
"037"	20210215- DSC_5205	5.50	3.30	5.20	5.70	6.10	5.20
"038"	20210215- DSC_5214	4.90	2.40	4.60	5.40	6.10	6.00
"039"	20210215- DSC_5214	4.00	2.00	2.20	5.50	4.78	4.80
"040"	20210215- DSC_5219	3.80	2.00	4.10	4.80	4.70	4.50
"041"	20210218- DSC_5233	5.10	2.50	2.20	4.30	4.10	4.30
"042"	20210220- DSC_5248	5.40	3.10	4.20	5.60	5.40	4.80
"043"	20210220- DSC_5249	5.20	2.50	2.50	5.10	5.60	4.30
"044"	20210220- DSC_5255	5.80	1.70	4.30	5.80	6.30	4.60
"045"	20210223- DSC_5273	6.00	1.80	5.10	4.40	4.50	4.30

"046"	20210223- DSC_5274	5.70	3.40	5.60	5.20	4.90	3.90
"047"	20210223- DSC_5278	5.30	2.60	4.80	3.90	4.00	4.30
"048"	20210223- DSC_5290	5.50	2.20	3.50	5.40	5.60	5.70
"049"	20210223- DSC_5307	6.10	2.90	4.30	6.00	6.00	5.50
"050"	20210223- DSC_5368	5.70	2.10	2.50	6.00	5.90	5.50
"051"	20210420- DSC_5663	4.20	2.10	2.70	4.30	4.00	2.80
"052"	20210420- DSC_5672	4.90	2.10	2.50	4.50	4.50	4.20
"053"	20210420- DSC_5678	4.50	1.70	1.90	5.10	4.80	4.50
"054"	20210420- DSC_5681	5.00	2.20	2.40	5.40	4.90	3.50
"055"	20210420- DSC_5684	4.50	2.10	2.80	3.40	3.50	4.50
"056"	20210420- DSC_5688	4.10	2.20	3.60	4.10	4.10	4.50
"057"	20210420- DSC_5694	5.20	1.90	3.10	4.40	4.50	4.10
"058"	20210420- DSC_5695	5.20	2.00	2.50	4.10	3.70	4.20
"059"	20210420- DSC_5698	5.60	1.90	1.90	4.10	4.10	5.10
"060"	20210420- DSC_5701	5.20	1.60	2.10	3.70	4.10	3.60
"061"	20210420- DSC_5704	5.50	2.30	2.80	3.50	2.80	4.40

"062"	20210422- DSC_5721	4.40	3.00	4.50	6.40	6.30	6.20
"063"	20210422- DSC_5742	5.60	2.40	2.70	3.20	3.90	5.60
"064"	20210422- DSC_5804	5.70	2.80	6.30	6.00	5.80	5.90
"065"	20210422- DSC_5807	3.50	2.30	5.00	5.30	5.60	4.50
"066"	20210422- DSC_5808	4.40	3.00	6.30	5.00	6.10	4.70
"067"	20210422- DSC_5812	3.50	3.40	5.00	6.10	5.60	5.70
"068"	20210422- DSC_5814	4.80	2.60	4.10	5.40	5.00	5.80
"069"	20210422- DSC_5820	4.00	2.80	5.80	5.50	5.80	5.90
"070"	20210422- DSC_5821	4.00	1.80	3.80	6.10	5.70	5.70
"071"	20210422- DSC_5823	4.10	2.60	3.90	5.60	5.60	5.90
"072"	20210422- DSC_5829	5.70	2.60	5.00	5.60	5.90	5.10
"073"	20210422- DSC_5836	5.60	3.00	4.10	5.30	4.90	4.90
"074"	20210422- DSC_5839	4.60	2.70	4.10	6.10	5.90	5.10
"075"	20210422- DSC_5842	4.33	3.10	5.30	5.90	6.20	5.80
"076"	20210422- DSC_5844	4.70	3.60	6.30	5.60	5.60	5.30
"077"	20210422- DSC_5848	5.00	2.00	5.30	5.80	5.10	5.50

"078"	20210422- DSC_5852	4.60	1.90	5.50	6.30	6.40	5.80
"079"	20210422- DSC_5857	4.60	3.30	6.00	5.20	5.40	5.80
"080"	20210422- DSC_5858	5.50	3.40	5.30	5.60	6.00	5.40
"081"	20210423- DSC_5890	4.50	3.20	3.80	5.50	5.80	5.50
"082"	20210423- DSC_5895	5.50	2.30	4.10	5.70	5.50	4.90
"083"	20210423- DSC_5898	5.60	2.00	3.80	5.30	5.20	4.30
"084"	20210423- DSC_5891	4.60	2.70	3.50	5.40	4.88	5.20
"085"	20210423- DSC_5893	5.00	1.80	2.70	5.20	5.10	5.00
"086"	20210423- DSC_5895	5.20	2.30	3.90	5.00	5.40	5.70
"087"	20210423- DSC_5898	5.90	1.50	2.70	5.40	5.20	3.80
"088"	20210423- DSC_5908	4.70	2.00	2.80	6.00	6.30	4.80
"089"	20210423- DSC_5904	6.30	2.10	2.60	5.70	5.80	5.40
"090"	20210423- DSC_5907	5.10	2.20	3.70	6.30	5.80	5.80
"091"	20210423- DSC_5911	5.40	1.30	1.90	6.30	6.10	5.70
"092"	20210426- DSC_6157	5.10	2.50	4.60	6.30	6.10	5.60
"093"	20210426- DSC_6176	6.10	2.70	3.60	6.70	6.80	6.20

"094"	20210426- DSC_6192	6.00	1.90	1.90	6.20	6.20	5.30
"095"	20210426- DSC_6201	4.90	1.90	2.20	2.60	2.90	4.90
"096"	20210426- DSC_6203	5.60	1.90	1.90	3.50	4.20	5.10
"097"	20210426- DSC_6204	5.10	2.30	2.80	3.90	4.10	4.60
"098"	20210426- DSC_6210	5.80	3.00	4.20	5.90	6.30	4.80
"099"	20210426- DSC_6210	5.30	2.30	3.00	6.20	6.10	5.50
"100"	20210426- DSC_6214	5.40	2.20	2.20	5.30	5.50	5.60
"101"	20210428- DSC_6300	4.30	2.50	2.30	4.70	5.60	3.50
"102"	20210504- DSC_6421	4.40	2.90	3.90	4.70	4.80	5.78
"103"	20210504- DSC_6425	5.30	2.90	5.60	6.00	5.90	5.80
"104"	20210504- DSC_6428	5.40	2.50	5.30	5.90	6.00	5.20
"105"	20210504- DSC_6432	5.80	2.50	4.50	6.30	5.90	5.50
"106"	20210504- DSC_6438	4.20	1.70	2.10	4.60	4.70	4.00
"107"	20210504- DSC_6441	4.10	1.80	2.20	5.00	4.80	4.30
"108"	20210504- DSC_6443	4.20	3.00	3.50	5.00	4.90	4.50
"109"	20210504- DSC_6454	4.90	3.20	2.60	5.70	5.80	5.70

"110"	20210504- DSC_6466	4.90	3.50	5.11	5.10	4.70	4.40
"111"	20210504- DSC_6470	5.10	3.20	4.10	6.10	6.00	6.10
"112"	20210505- DSC_6525	5.60	2.70	2.60	5.50	5.90	4.20
"113"	20210504- DSC_6498	5.30	1.40	2.20	5.80	5.30	5.70
"114"	20210504- DSC_6498	5.30	2.50	3.56	5.10	5.00	5.40
"115"	20210504- DSC_6503	5.20	2.40	4.00	4.50	4.40	5.10
"116"	20210505- DSC_6510	5.30	2.20	4.50	5.20	5.10	5.10
"117"	20210505- DSC_6510	5.50	1.70	2.40	5.80	5.40	5.40
"118"	20210511- DSC_6815	6.20	2.40	3.20	4.60	5.30	4.30
"119"	20210511- DSC_6815	5.60	1.60	2.80	4.90	5.50	5.30
"120"	20210511- DSC_6824	5.60	1.90	4.10	5.90	6.10	4.80
"121"	20210511- DSC_6832	5.20	2.60	3.60	5.30	5.00	4.44
"122"	20210511- DSC_6833	5.30	3.20	4.90	6.00	5.80	5.00
"123"	20210511- DSC_6880	4.60	1.90	4.50	5.10	5.20	4.00
"124"	20210511- DSC_6900	5.10	3.80	4.00	5.20	5.40	5.40
"125"	20210511- DSC_6902	5.00	3.30	4.00	5.90	5.80	5.80

"126"	20210511- DSC_6918	5.80	3.00	5.70	4.70	5.20	5.10
"127"	20210512- DSC_7031	5.20	2.30	2.90	5.40	5.10	3.30
"128"	20210512- DSC_7032	5.20	2.20	2.80	5.60	5.70	3.20
"129"	20210512- DSC_7051	5.10	2.50	3.56	5.70	5.20	5.60
"130"	20210512- DSC_7067	4.30	2.20	3.60	5.40	5.30	5.10
"131"	20210512- DSC_7072	5.20	2.40	2.50	6.30	6.30	5.80
"132"	20210517- DSC_7351	5.40	3.00	3.60	6.10	5.90	5.40
"133"	20210517- DSC_7353	5.80	2.80	3.80	6.50	6.70	4.60
"134"	20210517- DSC_7357	6.10	2.20	3.70	3.20	3.10	5.20
"135"	20210518- DSC_7394	5.40	2.00	1.90	4.44	5.20	5.00
"136"	20210518- DSC_7394	5.70	4.10	5.50	4.50	5.30	5.60
"137"	20210519- DSC_7657	5.90	4.40	4.90	4.90	4.00	5.30
"138"	20210521- DSC_7687	5.40	2.10	1.90	6.70	6.80	6.70
"139"	20210521- DSC_7844	4.10	2.80	4.00	6.00	6.10	5.60
"140"	20210521- DSC_7850	3.30	2.40	3.30	5.40	5.80	6.00
"141"	20210521- DSC_7884	5.40	2.40	2.50	6.80	7.00	6.11

"142"	20210521- DSC_7937	3.60	1.50	3.20	6.40	6.60	5.70
"143"	20210521- DSC_7952	6.10	2.40	3.20	5.90	6.20	4.20
"144"	20210521- DSC_7952	6.00	2.50	2.80	5.20	5.50	5.00
"145"	20210604- DSC_8178	4.70	3.40	3.80	5.00	5.20	5.60
"146"	20220509- DSC_9523	4.80	1.90	3.90	5.70	5.60	5.20
"147"	20220609- DSC_9729	3.20	2.60	3.40	5.20	4.50	4.90
"148"	20220609- DSC_9733	3.20	2.30	2.70	5.10	5.70	4.30
"149"	20220609- DSC_9735	4.60	2.40	2.40	5.10	4.80	4.90
"150"	20220609- DSC_9745	4.80	2.00	2.30	4.60	4.10	4.40
"151"	20220609- DSC_9747	5.30	1.90	3.40	5.10	4.60	4.10
"152"	nII (Mount Argus)	4.60	2.20	3.20	5.20	5.80	5.50
"153"	nIII (Mount Argus)	5.20	2.00	1.89	4.10	5.10	5.90
"154"	nX - detail (Harrington St.)	5.40	2.90	2.40	5.40	5.10	4.30
"155"	nX Annunciation (Harrington St.)	3.60	1.60	4.30	6.10	6.50	6.00

	nX Tracery						
"156"	(Harrington St.)	5.40	2.40	4.50	5.70	5.80	4.10
	nX Visitation						
"157"	(Harrington St.)	4.00	1.90	3.80	6.10	6.10	5.80
	nX						
"158"	(Harrington St.)	4.10	2.40	2.90	6.00	5.90	5.40
	nXV						
"159"	(Terenure, St Joseph)	5.40	3.00	3.10	6.10	6.50	5.10
	sXV						
"160"	(Terenure, St Joseph)	6.40	2.00	2.10	2.70	3.10	3.80

Appendix C – Images used in the memorisation phase of eye-tracking study. The original image names can be identified in Appendix B.

Image Identification Number
003
017
025
042
043
044
052
057
058
088
089
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099
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122
132
134
143
144
150
151

**Appendix D - Images used in the online memory study. The original image names can be identified
in Appendix B.**

Image Identification Number
001
002
003
005
006
008
012
013
014
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026
028
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030
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Appendix E - Opacity and Blur Values Applied per Stained-Glass Window Lighting Category

Light Variation Type	Blur Value	Opacity Value	Frame Number Selected for Static
			Stimuli
Rain	None	200	075
Cloud	6	200	075
Firework	None	125	059
Lightning	4	150	006
First bird (frames 000 -			
074)	4	100	041
Second bird (frames			
075 - 150)	6	100	041
Tree	2	150	075