SHAPE PERCEPTION, HARVEST DESIGN AND FOREST AESTHETICS

by

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Abstract

The aesthetic value of a landscape is a primary aspect of human-landscape interactions, as it provides a critical connection between humans and ecological processes as well as influences public attention and support to its ecological quality. Along with the ecological well-being of the landscapes, the maintenance of aesthetics is also critical in ensuring sustainable management of the forest. This thesis focuses on seeking new ways to effectively manage forest aesthetics, particularity on finding ways to mitigate the conflict between aesthetic quality and the demand of forest resources. The research strives to identify and quantify visual characteristics of harvest blocks in relation to their effects on individual aesthetic evaluations.

The first experiment investigated the effects of context and shape complexity. Results indicated shape complexity as the largest predictor of preference, where preference increased as complexity increased. This finding indicates that increased complexity in harvest block design can be seen as a positive aesthetic variable. Context also demonstrated significance in influencing preference ratings, to a small extent. Subjects with environment focuses in their area of study demonstrated a stronger complexity effect than those from non-environment focuses, indicating a potential link between academic discipline and aesthetic preference.

The second experiment explored several potential shape characteristics affecting individual aesthetic preference. Five characteristics were investigated: context, angularity, edge number, edge angle, and intrusion. Results indicated angularity had the largest effect on preference ratings. Subjects showed a strong preference towards curved designs, particularly in the context of harvest blocks. Although angularity also interacted with a number of variables, its effect

prevailed and appeared to be robust. This finding implicates that perceptual gains can be achieved by curving the edges or the contour of the harvest block.

The results of this research may lead to more effective visual resource management in the area of harvest block design. The findings presented can provide helpful information in public perception and preference of the landscape to forest designers and managers. Results suggest that curved designs with medium levels of shape complexity should be the preferred method of harvesting, particularly in visually sensitive areas.

Preface

This thesis was developed through my passion for the environment and psychology. I have always been interested in understanding the relationships between humans and nature, particularly in the perception of the environment. This thesis investigates different characteristics of harvest block design as well as how and to what extent they can influence human aesthetic evaluations of the landscape. This research represents new insights for forest management, especially in visually sensitive areas.

This thesis consists of four chapters. The introduction and conclusion were written entirely by me.

A version of chapter 2 has been submitted for publication. I wrote the manuscript and took the lead role in developing the images and facilitating the computer survey. Dr. Brent Chamberlain, Dr. Robert Kozak, and Dr. Michael Meitner were co-authors of this paper. Dr. Brent Chamberlain developed the survey interface used for this research. Dr. Michael Meitner helped instruct the experimental design and statistical analysis of the data. He also provided an extensive review of the manuscript. Dr. Robert Kozak also provided substantial support in data analysis and in the review of the manuscript. The research required the approval of UBC's Behavioural Research Ethics Board and was approved with ID H10-01209-A002.

Table of Contents

List of Tables

List of Figures

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Dedication

“All that we are is the result of what we have thought. The mind is everything. What we think we become.” – Buddha

I would like to dedicate this thesis to my loving and supportive parents and step-parents. You are the ones that made this possible.

Chapter 1: Introduction

The relationship between aesthetics and ecology in the context of landscapes is intimate yet complex (Gobster, Nassauer, Daniel, & Fry, 2007). This relationship has significant implications for those interested in landscape ecology including natural scientists, geographers, planners and mangers, as well as social scientists interested in the causes and consequences of landscape change. As stated by Gobster et al. (2007), the study of aesthetics helps in the understanding of landscape change in three ways: 1) landscape aesthetics provides a crucial connection between humans and ecological processes; 2) aesthetic experience is a key driver of landscape change; and 3) the perceived aesthetic value of a landscape can influence public attention and support of its ecological quality. The incorporation of aesthetics in landscape planning, design and management is critical in the protection and enhancement of ecological goals.

The aesthetic values of a landscape are a primary aspect of huamn-landscape interactions (Gobster, 1999; Kaplan & Kaplan, 1989), yet the visual characteristics of this are difficult and sometimes controversial (Walker, 1995) to define (Sang, Miller, & Ode, 2008). Research in the development of visual quality indicators has found common ground in objectively measuring aspects within the landscape while relating these to public preferences and experiences (Lothian, 1999; Sang et al., 2008; Tveit, Ode, & Fry, 2006; Zube, Sell, & Taylor, 1982). Visual landscape description and inventory methodologies have been developed to address issues of aesthetics and public perceptions of forested landscapes in the larger context of forest management (Sheppard, 2004). In the United States, aesthetics was fully recognized as an essential component of visual resource management (VRM) under the National Environmental Protection Act (NEPA) in 1969 in response to negative public reactions for existing timber harvest practices (Chamberlain & Meitner, 2012; Ribe, 2005; Sheppard, 2004; Smardon, 1984; USDA Forest Service, 1995). Similar VRM frameworks have been established in British Columbia, Canada under the Forest Range and Practices Act in 2004; with the goal to "…ensure that the levels of visual quality desired by society are achieved on all crown land in scenic areas in keeping with the concepts and principles of integrated resource management" (B.C. Ministry of Forests, 2001, 2004).

One of the primary levers that forest managers have in mitigating the visual impacts of their activities is the design of harvest blocks, which has long been an important characteristic of the landscape when considering the goal of balancing numerous ecological, economic and social concerns. The overwhelming trend in the industry has been to simplify the design of harvest blocks to increase economic efficiency and safety. However, various issues—such as the impact of these designs on habitats for various wildlife species— have led to the need to balance simplicity with additional design criterion (Gobster, 1999; Picard & Sheppard, 2001). This is also true for the effects that harvest block design has on visual aesthetics, although these relationships have yet to be fully explored in the literature.

1.1 Visual Quality Indicators

Initiated in early 1970s, the development of visual quality indicators has played an important role in analyzing landscape changes due to natural and human factors. Both landscape ecologists and environmental psychologists have developed a large number of indicators to determine the aesthetic quality of landscapes, mainly focusing on elements of ecological function as well as different aspects associated with anthropogenic functions of the landscape (Ode, Hagerhall, & Sang, 2010). Tveit et al. (2006) has developed a full review of existing visual quality indicators including stewardship, coherence, disturbance, historicity, visual scale, imageability, complexity, naturalness, and ephemera. These nine concepts will be discussed in detail in the following section.

1.1.1 Stewardship

Stewardship is defined as the presence of a sense of order and care. It usually reflects active and careful human management for the landscape (Tveit et al., 2006). According to Nassauer (1992), *ecology* is a scientific concept whereas *landscape perception* is a social process; planning and policy must include socially-recognized signs of beauty and stewardship to demonstrate human care for ecological systems. Nassauer (1995) has further enhanced the notion of stewardship by presenting "cues of care", such cues refer to cultural symbols used to plan novel ecosystems in inhabited landscapes. For instance, straight, weed-free rows of corn on a farm would indicate care for the landscape. The concept of care was further developed as visible stewardship and defined as "…people who are linked to it, rooted in it, invested in it, working in it in a respectful, symbiotic, and continuously vigilant manner, perhaps even from generation to generation" (Sheppard, 2000). This theory does not focus on whether the landscape looks natural, orderly, or controlled; it emphasizes on the real connection between the people and landscape. An experiment conducted by Hands & Brown (2002) investigated the visual preference of ecological rehabilitation of decommissioned industrial lands. Computerized visual simulations of landscapes at establishment and mature stages of development were used and rated by preference by the participants. Results demonstrated a significant increase in visual preference when "vernacular cues to care" strategies such as the addition of bird boxes were present in the landscape presented.

1.1.2 Coherence

Coherence – also referred to as harmony, readability, and unity – is defined as "the ability to see and comprehend the pattern inherent in a scene (the opposite to chaos)" (Bell, 1999). A coherent landscape often provides the observer with a sense of order and direction, both in time and space (Kaplan & Kaplan, 1989; van Mansvelt & Kuiper, 1999). Both van Mansvelt & Kuiper (1999) and Bell (1999) has noted that the comprehension of the whole is more important than that of the individual parts. Coherence within a landscape also refers to the relationship between land use and natural conditions (Kuiper, 1998; van Mansvelt & Kuiper, 1999). As summarized by Tveit et al. (2006), van Mansvelt & Kuiper (1999) proposed that a coherent landscape should reflect its foundation in geomorphology (vertical coherence), the interconnectedness of its features and structure as a whole (horizontal coherence), and the development of landscape through time and in response to seasonal or vernal patterns (temporal coherence). Often preference is associated with landscapes consisting of coherent aspects (Tveit et al., 2006).

1.1.3 Disturbance

Tveit et al. (2006) defined disturbance as lack of contextual fit and coherence, as well as modifications and interventions happening in the landscape, of both temporary and permanent character. As demonstrated in existing literature, visual disturbance is mostly induced by human activities such as forestry, mining, road construction, utility corridors, agriculture, and buildings and infrastructures. A number of parameters have been established in response to directly quantify and measure the amount of human disturbance. The Visual Intrusion Index measures the loss of amenity resulting from environmental disturbance and pollution (Hopkinson, 1971). The Visual Magnitude proposed by Iverson (1985) measures the slope, aspect, and distance of a land plane or object from the observer; this parameter can be used directly in assessing visual disturbance. Stamps (1997) successfully developed a paradigm for distinguishing the significance of visual impacts. The British Columbia (BC) Forest Services has identified these activities as Visual Alteration and calculates such information as part of the Visual Landscape Inventory (VLI) procedures (B.C. Ministry of Forests, 1997a). Moreover, a public perception study focusing on clear-cuts conducted by the BC Forest Services (1996) has found that landscapes with low percentage of human modification were perceived as most acceptable.

1.1.4 Historicity

As reviewed by Tveit et al. (2006), historicity can be defined through two dimensions: historical continuity and historical richness. Historical continuity refers to the visual presence of different time layers with influences by the age of each layer; historical richness is associated with the amount, condition and diversity of cultural features. The presence of historical elements is crucial for landscape perception and preference as it amplifies the existing elements in landscapes (Lowenthal, 1985; Tveit et al., 2006). The incorporation of existing historical cultural infrastructures into present landscapes can provide depth, richness, inspiration, and aesthetic enjoyment (Yahner & Nadenicek, 1997). They suggested that history can be of use to fast growing communities in two ways: 1) it can provide lessons and guidance, and 2) it can enhance the quality of life in present communities. Furthermore, Yahner & Nadenicek (1997) argued that the difference in form, material, wear, patina, and scale between historical and recently built structures are important for the visual quality of the landscape; in fact, artifacts can be appreciated for their aesthetic qualities and provide the landscape with texture and diversity.

1.1.5 Visual Scale

The concept of visual scale refers to the perceptual units related to the experience of landscape rooms, visibility, and openness (Tveit et al., 2006). Moreover, potential indicators of the visual of a landscape includes viewshed size, viewshed form, depth of view, degree of openness, grain size, and number of obstructing objects. Viewshed refers the visible form of the environment from a fixed vantage point. This concept is strongly linked to visual quality and landscape preference (Hanyu, 2000; Tveit et al., 2006; Tveit, 2009; Vining, Daniel, & Schroeder, 1984; Wing, 2001). Both Hanyu (2000) and Clay & Smidt (2004) identified the degree of openness in a landscape as accountable in improving preference levels. Spaciousness, has also been established as a positive predictor of preference (Herzog, 1985). Visual scale analysis tools have been developed based on techniques of visibility analysis in a geographical information system (GIS) environment (Germino, Reiners, Blasko, McLeod, & Bastian, 2001; Wing, 2001). In a study conducted by Tveit (2009) examined preference levels of photos developed using two photo-based indicators of visual scale: Percentage Open Land in the View and Size of Landscape Rooms. Results indicated that the visual scale indicators tested were both good predictors of preference for the student group.

1.1.6 Imageability

The imageability of a landscape refers to the qualities of a landscape present through elements or holistically, landmarks and special features, both natural and cultural, making the landscape distinguishable and memorable (Tveit et al., 2006). Imageability was established by Lynch (Lynch, 1960) and defined as “the quality in a physical object which gives it a high probability of evoking a strong image in any given observer”. This concept is also referred to in the literature as vividness (Litton, Sorensen, & Beatty, 1974) and the spirit of place or genius loci (Bell, 1999; Norberg-Schulz, 1980). Litton et al. (1974) defines vividness as "that quality in a landscape which gives it distinction and makes it visually striking" and usually links it strongly to water bodies. The spirit of place or genius loci can be described as landscapes with sensations of beauty or sublimity present (Bell, 1999; Norberg-Schulz, 1980). In layman terms, imageability refers to the qualities that are special for a landscape and such qualities often provide the landscape with a strong identity (Tveit et al., 2006). These special qualities can be natural, such as the present of water, or cultural, such as historical infrastructures.

1.1.7 Complexity

Complexity has been established as a key indicator of visual quality (Kaplan & Kaplan, 1989); it can be defined as the diversity and richness of landscape characteristics and features with respect to their interspersion (Tveit et al., 2006). Ode, Tveit, & Fry (2008) has provided an extensive literature review of experience-based complexity. They organized various definitions of complexity into three dimensions: 1) the distribution of landscape elements; 2) the spatial organization of patterns; and 3) the variation and shape of elements and patterns. In terms of the first dimension, the definition of complexity stemmed from the works of psychology where complexity can be described as the number (richness) and/or diversity (arrangement) of visual stimulus (Berlyne, 1974; Kaplan & Kaplan, 1989). The measurement of complexity, in this case, usually focuses on examining how many landscape elements are present and/or how much variety is present in land cover (De la Fuente de Val, Atauri, & De Lucio, 2006; Hunsaker et al., 1994). With respect to the spatial organisation of patterns dimension, Kaplan & Kaplan (1989) has linked coherence to complexity and has concluded that something appears messy is not necessarily the result of too much complexity, but might be the result of low coherence. As a result, the spatial organization of patterns can be seen as a major component of perceived complexity. Another characteristic of perceived complexity within a landscape is the variation and shape of elements and patterns; existing research has recognized fractal geometry and edge measurements as indicators of shape complexity. Fractal patterns –typically self-similar patterns and displays across different spatial scales – are often found in nature; for instance, a tree where a branch is similar to the whole tree. Fractal dimension has been as a common shape complexity index (Hagerhall, Purcell, & Taylor, 2004; Spehar, Clifford, Newell, & Taylor, 2003). Other measurements of shape complexity include the number of edges, which can either be defined as total edge length (Dramstad, Fry, Fjellstad, Skar, & Helliksen, 2001) or edge density (Baessler & Klotz, 2006). These edge measurements are also used to quantify the complexity of pattern; in which high levels of edge length and density could indicate a highly fragmented landscape and/or irregularly shaped patches (Ode, Hagerhall, & Sang, 2010).

1.1.8 Naturalness

Naturalness can be described as the relation of how close a landscape is to a preconceived natural state (Tveit et al., 2006). A number of environmental psychologists have identified naturalness as a key aspect of visual quality, linking it back to evolutionary theories of preferences (Gobster, 1999; Kaplan & Kaplan, 1989; Purcell & Lamb, 1998; Ulrich, 1979). Tveit et al. (2006) has listed a number of potential indicators of naturalness including fractal dimension, vegetation intactness, percentage area with permanent vegetation cover, presence of water, percentage area water, presence of natural feature, management style and intensity, naturalism index, and degree of wildness. Ode et al. (2009) have furthered confirmed the relationship between landscape preference and naturalness. Three indicators of naturalness, including level of succession, number of woodland patches and shape index of edges, were explored and demonstrated significance. Fractal dimension (fractured shapes possessing repeating patterns when viewed at increasingly fine magnifications), as another indicator of naturalness, could provide part of the explanation to the relationship between preference and naturalness (Hagerhall et al., 2004; Spehar et al., 2003). Studies have also revealed that there is a preference for half-open landscapes over very open landscapes and closed ones (Tveit, 2009), supporting both the prospect-refuge theory (Appleton, 1996) and the information processing theory (Kaplan & Kaplan, 1989).

1.1.9 Ephemera

The concept of ephemera refers to landscape changes throughout the year due to weather conditions, which could alter the perceived landscape on a short-term basis (Tveit et al., 2006). Litton (1972) referred to this phenomenon as “the effect of natural phenomena occurring at a given point in time, producing a visual product that is characteristic of that moment”. Seasonal change (human imposed and natural) as well as weather related changes are important to the experience of a landscape, also are an essential part of the landscape itself. For instance, the presence of flowers has been identified as a predictor of preference (Akbar, Hale, & Headley, 2003; Gourlay & Sleet, 1998). The different state of bodies of water in a landscape has also demonstrated importance relating to aesthetic preference (Tveit et al., 2006).

1.2 Harvest Block Design

For forested landscapes, one important visual indicator of preference is the percentage of visible alteration; landscapes with a low percentage of human modification are perceived as most acceptable (B.C. Ministry of Forests, 1996, 1997b; Paquet & Belanger, 1997). Green-tree retention levels and patterns have been found to be critical in relation to perceived scenic beauty; higher preference was associated with increased retention level only with dispersed retention pattern (Ribe, 2005, 2009). Furthermore, all levels of aggregated retention demonstrated low preference. The design of harvest blocks has recently gained importance in relating landscape preference to individual aesthetic evaluations. Existing studies have determined that the design of harvest blocks can be effective in improving aesthetic evaluation of the landscape, both in the background and deeper middle-ground distances from the observer point (Karjalainen & Komulainen, 1999; Ribe, 2002, 2005). Palmer et al. (1995) as well as Paquet & Belanger (1997) further concluded that natural-looking harvest blocks can have an impact on preference only when few harvests are present. However, contrary to these findings, recent experiments conducted by Chamberlain & Meitner (2012) have found that the shape of a harvest block may, in fact, have an effect in improving the overall aesthetic of the landscape. A number of experiments led by Chamberlain & Meitner (in press) attempted to fill this gap by investigating the effects of harvest block design on aesthetic preferences. Results from these experiments will be discussed in the following section. Variables tested include shape, complexity, aspect ratio, percent alteration, and retention. These variables were developed based on literature in landscape aesthetics.

1.2.1 Basic Shape

In the four experiments, the largest effect when predicting individual preference of a harvest block was caused by its basic shape. In experiment 1, this was referred to as a geometric primitive; square, trapezoid, triangle, and circle were tested for preference. Results revealed circles were preferred most, followed by triangles, trapezoids, and squares. In experiment 2, the shape of harvest blocks were based on two conditions: square-type and circle-type. Again, square-type shapes produced lower ratings. Interestingly, an interaction effect of shape and percent alteration was found; in which participants rated a circle-type shape at 18% harvest higher in preference than a square-type shape at 6% harvest. In experiment 3, retention blocks were added. The external shape (harvest block) was held constant as a curved shape with medium complexity, while three conditions of the internal shape (retention block) varied as square, hybrid (a combination of angular and curved edges), and circle. A linear preference was found from circle to hybrid to square shapes. In experiment 4, retention blocks were included in the harvest blocks. Square-type and circle-type shapes were used in both the external (harvest block) and internal (retention block) shapes. Results indicated a reduction in preference in the presence of square-type shapes regardless of the location, with the most influential being square-edged external shape. Shape has demonstrated significance in predicting preference based on these results; however, shape was defined solely on the angularity of the edges. Thus, a more comprehensive investigation on defining shape and its associated characteristics is needed.

1.2.2 Complexity

Complexity, in this case, has been defined as the irregularity of the shape, and was determined based on a combination of the number of edges, turns, and angular variability. Complexity was held in three levels: low, medium, and high. Complexity has demonstrated significance in predicting preference, where subjects preferred harvest blocks with medium and high levels of complexity when compared to those with low complexity. This finding is comparable to a number of perceptual experiments in the field of psychology on the same topic.

1.2.3 Percent Alteration

Percent alteration can be described as the amount harvested. In experiment 2, percent alteration was manipulated at four levels: 2%, 6%, 12%, and 18%. As demonstrated in existing research, aesthetic preference increases as the amount harvested decreases. In other words, the lower the alteration, the better.

1.2.4 Retention

Retention blocks were added to the variables tested in experiment 3 and 4. Experiment 3 investigated the effect of number of blocks have on preference. Number of retention blocks varied at one and three while holding the amount retained stayed the same. Participants displayed a higher preference for one retention block over three, although the absolute difference was small. Experiment 4 added another two variables: percent retention and retention pattern. Number of retention blocks was kept at three, six, and nine. Percent retained was held at three levels: 15%, 30% and 45%. Retention patterns included two conditions: dispersion and aggregate. Results revealed that both six and nine retention blocks were rated higher in preference than three retention blocks, although nine retention blocks were rated lower than six retention blocks by a small percentage. A linear preference was found with percent retained, with 45% demonstrated the highest preference rating, followed by 30% then 15%. Furthermore, dispersed retention blocks showed a higher preference than retention blocks with an aggregated pattern.

1.2.5 Aspect Ratio

Aspect ratio was defined as the elongation of a shape and accounted for it by drawing a box around the full extent of the harvest area and measuring the ratio of width divided by height. Three levels were used: low, medium, and high. Results indicated a small effect of aspect ratio, with small differences in mean ratings in the three levels tested.

1.3 Shape Perception and Preference

The aforementioned experiments served as the foundation of this research. This research focused exclusively on the shape variable alone as it demonstrated the largest effect among all the variables tested. Most importantly, the concept of shape has been studied comprehensively in the field of psychology. This research attempts to make connections between landscape aesthetics and visual psychology. By focusing on shape, this research hopes draw parallels between the two disciplines. The psychology of perception has a long history of studying how visual features influence aesthetic evaluation and preference. Research on shape has proposed a number of predictors of preference including angularity, symmetry, complexity, prototypically, fractal dimension, balance, and size. These characteristics will be discussed in detail in the following section.

1.3.1 Angularity

Humans' attitudes toward basic shapes, such as a preference for circles over triangles, may be biologically predisposed in that people inherently know that sharp-edged objects are more dangerous than rounded ones (Sommer, Sommer, & Cho, 2004). Angular objects with sharp angles indicate danger and therefore it is associated with threat and risk, whereas rounded objects are less likely to cause injury when in contact. Threat-specific physical primitives are processed as a high priority, possibly using rapidly available low-level sensory information (Bar, 2003). As indicated by Bar & Neta (2006), the human cortex might be designed for detecting features associated with threat and risk quickly. The amygdala has been shown to respond to implicit, non-conscious cues of threat (Whalen et al., 1998). There is a possibility that human brains have evolved to detect sharp features quickly which can help signal a potential danger (Bar & Neta, 2007). Furthermore, studies indicate that rounder faces are more liked and generally perceived as more attractive than more angular faces (Bar & Neta, 2006).

A number of studies conducted by Bar and Neta (2006 & 2007) has identified humans' preference for objects with curved features. They concluded that emotionally neutral objects with primarily pointed features and sharp angles would be preferred significantly less than corresponding objects with curved features (Bar & Neta, 2006). Participants were shown grayscale pictures of 140 pairs of real objects. The items in each pair had the same semantic meaning and general appearance with the difference of the curvature of their contour (e.g., square shaped watch vs. circular shaped watch). Each participant was asked to view one member of each pair (either the sharp-angled or the curved item). All participants were required to make a like/dislike forced-choice decision about each picture based on their immediate reaction. Results demonstrate that participants liked the curved objects significantly more than the control objects.

This finding can be directly linked back to the experiments conducted on harvest block design, where circle-typed harvest blocks were rated higher in preference than their angular counterparts.

Bar & Neta (2007) further supported their findings by conducting a follow-up study using human neuroimaging. The results of this study revealed that the amygdala—a brain structure involved in fear processing and that shows activation proportional to arousal—is significantly more active for everyday sharp objects (e.g., a clock with sharp corners) compared with their curved contour counterparts (Bar & Neta, 2007). The same stimuli conditions from the 2006 study were used; amygdala response between conditions was also compared. The studies focused on the difference in functional magnetic resonance image (fMRI) activity elicited in the amygdala under different conditions. Results indicated that in the right amygdala, a significantly greater activation for objects with sharp contours was found. The results in the left hemisphere were very similar. The increased bilateral amygdala activation for sharp-angled objects was consistent regardless of participants' sex, age, or education level.

Similar experiments led by Silvia & Barona (2009) tested the angularity effect while controlling symmetry, prototypically, and balance. In experiment 1, the stimuli set selected from Wilson & Chatterjee's (2005) Preference for Balance Test, which included circles (curved) and hexagons (angular) displayed separately while the level of balance varied. Moreover, both circles and hexagons are symmetrical along vertical, horizontal, and diagonal axes. The typicality of the stimuli set was also controlled by including equal numbers of circles and hexagons at each level of balance. Results indicated a main effect of angularity and found no effect of imbalance on preference. In experiment 2, black-and-white random asymmetrical polygons were used as the stimuli set, half were digitally rounded to allow comparison for preference between the angular and curved version of the same polygon. Appraisals of the polygon's complexity were also measured. Results also indicated a main effect of angularity where subjects preferred the rounded polygons to the angular polygons. As demonstrated by these findings, the angularity effect appears to be robust.

A series of experiments conducted by Larson, Aronoff & Stearns (2007) attempted to determine whether the same preferential processing (curved vs. angular) was present for the shape of downward-pointing “V”. Previous work has indicated that angular V-shaped images conveyed an angry meaning and are usually perceived as being more negative (Aronoff, Barclay, & Stevenson, 1988; Aronoff, 2006; Lundqvist, Esteves, & Ohman, 1999). Larson, Aronoff & Stearns (2007) found that, when presented with other shapes, downward-pointing V’s were recognized quickly with great accuracy and rated as more aversive. Additionally, identical shapes pointing upward were recognized slower as well as less accurately. An explanation for such results is that simple geometric shapes with underlying facial expressions such as the downward-pointing “V” are capable of expressing emotional meaning, suggesting that emotional information can take precedence and is processed preferentially (Larson, Aronoff, & Stearns, 2007; Vuilleumier, 2005). Larson et al. (2008) further supported this notion by presenting evidence that simple non-contextual geometric shapes containing downward-pointing V-shaped angles can trigger the perception of threat by provoking greater activation of the amygdala, than do presentations of upward-pointing V-shapes.

Another interesting study led by Zhang, Feick, & Price (2006) examined the possible linkage between self-construal and aesthetic preference for rounded versus angular shapes. Previous research found that an independent self-construal is associated with a confrontation approach to conflict resolution, whereas an interdependent self-construal is associated with compromise (Zhang, Feick, & Price, 2006). In addition, aesthetic preference literature reveal that angular shapes tend to produce confrontational associations, and rounded shapes tend to generate comprise associations (Zhang et al., 2006). A self-construal priming task (independent condition vs. interdependent condition) was completed first by the subjects. During the second part of the survey, subjects were presented with either a public situation or a private situation. Then, the shape stimuli (rectangular vs. rounded were presented to the subjects for preference evaluation. In addition, subjects were asked to complete the 21-item conflict resolution style scale; a high score would mean preference for the confrontational over the compromise approach to conflict resolution. Arousal level was also measured. Results indicate that individuals primed with an independent self-construal (compared to an interdependent self-construal) are likely to perceive angular shapes as more attractive. More specifically, self-construal priming acted on participants' approach to conflict resolution rather than on arousal level to affect shape aesthetic preference.

1.3.2 Symmetry

Extensive research demonstrate that humans and certain other species find symmetrical patterns more attractive than asymmetrical ones (Enquist & Arak, 1994). It is proposed that symmetry also plays a crucial role in terms of aesthetic preference. In particular, preference of shapes is strongly biased toward axes of global symmetry (Palmer, 1985).

Results from an experiment conducted by Eisenman & Rappaport (1967) demonstrated a tendency to prefer symmetry regardless of the complexity levels presented. A follow-up experiment by Eisenman (1967) has found that subjects preferred symmetrical shapes and rejected complexity to a highly significant degree, though subjects did not show strong preference for simple shapes either. Eisenman & Gellens (1968) led a similar study focusing on complexity-simplicity and symmetry-asymmetry. Subjects had to choose between complex-asymmetrical polygons, complex-symmetrical polygons, simple-asymmetrical polygons, and simple-symmetrical polygons. Data collected suggested a strong tendency to prefer complex-symmetrical shapes.

It has long been accepted that bilaterally symmetrical patterns, those which have their axis of symmetry vertical are more saliently symmetrical than patterns with axis of symmetry at another orientation (Wenderoth, 1994). A number of experiments conducted by Wenderoth (1994) attempted to address the relative salience of different orientations of axis of symmetry. In experiment 1, participants were asked to discriminate between symmetric or random-dot patterns when the axis of symmetry was at one of 18 different orientations, spaced 10° apart, both clockwise and counter-clockwise of vertical to horizontal. Results demonstrated that vertically symmetrical patterns was most salient, followed by horizontally symmetrical patterns. Additionally, performance for precisely diagonal axes was better than those with surrounding axis orientations. For experiment 2, the same stimuli and procedures were used with a time limit. Results confirmed the hypothesis that symmetry detection is superior at the diagonal than around it; subjects tended to direct attention to the cardinal axes and the midpoint between them. Experiment 3 was conducted to replicate results from the previous two experiments. Data indicated again, that vertically symmetrical patterns were most salient among all other orientations.

A robust body of research proposes that preferences for symmetry have evolved in both humans and animals because the degree of symmetry in signals indicates the signaller's quality (Enquist & Arak, 1994). Humans' preference for symmetrical patterns appears in response to biological signals, in exploratory behaviour and in aesthetic response to pattern (Enquist & Arak, 1994).

Enquist & Arak (1994) raised the possibility that the human aesthetic preference is based on general principles of perception that have been critical during the evolution of biological signals. Furthermore, they proposed that preference for symmetry may arise as a by-product of the need to recognize objects regardless of their position and orientation in the visual field. Another possible explanation is that some morphological symmetries arise inevitably from developmental processes (Enquist & Arak, 1994). Finally, existing research suggest that preferences for symmetry may have evolved for adaptive reasons connected with mate choice (Johnstone, 1994).

1.3.3 Complexity

Attneave (1957) saw the term complexity as an ill-defined variable and has attempted to define complexity by measuring subjects' ratings of the complexity of nonrepresentational shapes in relation to their physical characteristics. The shapes presented were constructed by systematically varying certain physical characteristics while the remainder were randomly determined. Results indicated that about 90% of the variance of ratings was explained by 1) the number of independent turns in the contour, 2) symmetry, and 3) the arithmetic mean of algebraic differences, in degrees, between successive turns in the contour. Although number of turns accounted for nearly four-fifths of the variance of the judgements, the definition of complexity cannot be solely based on this single variable.

With regards to the relationship between preference and complexity, Berlyne's (1958, 1963) theory stated that preference for any stimulus is determined by its arousal potential. A series of experiments led by Berlyne (1958, 1963) examined the influence of complexity and novelty in visual figures on orienting responses. Stimulus material (a pair of figures at a time) was presented to the subjects; order and duration of fixation on one figure over the other within each pair were measured. One member of each pair was considered as “less complex (LC)” and the other as “more complex (MC)” based on the following categories: 1) irregularity of arrangement, 2) amount of material, 3) heterogeneity of elements, 4) irregularity of shape, 5) incongruity, and 6) incongruous juxtaposition. Results revealed that the mean of fixation time for the MC figures was greater than the mean of fixation time for the LC figures; this effect was found in every single pair presented. Subjects tended to spend more time on the inspection of more complex or conflict-arousing stimulus material. A follow-up study was conducted to further examine complexity and incongruity variables as determinants of exploratory choice and evaluative ratings (Berlyne, 1963). In addition to the six categories mentioned above, another three was added: 1) number of independent units; 2) asymmetry; and 3) random redistribution. Nine categories of pairs of visual patterns were used; each having one considered as “less irregular (LI)” and one considered “more irregular (MI)”. Results indicate a significant tendency to rate MI patterns as more interesting and LI patterns as more pleasing. Based on these results, Berlyne concluded that the relationship between preference and arousal potential is hypothetically described by the Wundt curve – stimuli with medium arousal potential are most liked. This theory has been widely confirmed.

An experiment conducted by Day (1967) investigated subjects’ ratings on three scales – subjective complexity, pleasingness, and interestingness – on a series of random-shaped polygons varying in number of sides ranging from four to 160. He concluded that subjective evaluations of complexity continued to rise with the increase in number of sides within the polygon. Pleasingness ratings peaked at 6-sided and 28-sided levels then significantly decreased with increased complexity. Interestingness evaluations increased to a peak at the 28-sided polygon and remained high throughout the rest of the series.

A series of experiments led by Martindale, Moore, & Borkum (1990) aimed to test findings derived from Berlyne's theory of aesthetic preference. Complexity (number of turns in a polygon), size, meaningfulness (measured by the number of realistic items a polygon reminded subjects of), and colour of the polygons were controlled. Contrary to Berlyne's findings, results indicated that preference was related to the number of turns in a polygon by monotonic rather than inverted-U functions. However, there was some evidence for the Wundt curve, in the case of – but not always – weak stimuli (e.g., non-prototypical colours, non-preferred colours, small sizes, and noncomplex stimuli). With respect to strong stimuli, preference is more likely to be related to its predictors in a monotonic manner. Moreover, they suggest other variables such as prototypicality/meaningfulness may have been an important determinant for preference.

1.3.4 Prototypicality

While Berlyne's theory dominated the field of experimental aesthetics, a number of psychologists believe that prototypicality (the degree to which an item is an exemplar of the category of which it is a member)/meaningfulness (by the number of realistic items the stimuli reminded subjects of) is the main determinant of aesthetic preference (Hekkert & Snelders, 1995; Martindale et al., 1990; Martindale, Moore, & West, 1988; Martindale & Moore, 1988). They believe that "aesthetic preference is hypothetically a positive function of the degree to which the mental representation of a stimulus is activated" (Martindale & Moore, 1988). In other words, preference should be given to more typical stimuli. A series of experiments conducted by (Martindale & Moore, 1988) investigated on the effects of priming and protoypicality have on colour preference. Subjects were either primed with a category-name or a colour first, and then were required to rate prototypical and non-prototypical coloured chips for preference. Results indicated that category-name priming increased preference for prototypical colours and decreased preference for non-prototypical colours. Colour-priming, on the other hand, generally decreased preference for both prototypical and non-prototypical colours. With respect to the effect of prototypicality, results suggested a larger preference for more prototypical stimuli. Similar studies led by (Martindale et al., 1988) also suggested typicality predicated for preference 8 or 9 times more than did long-term novelty, short-term novelty, or mere exposure.

In terms of linking contextual cues to shapes, Martindale et al. (1990) conducted several experiments testing Berlyne's theory and concluded that the relationship between number of turns and preference was monotonic, preference increased as edge number increased. Complexity (number of turns), size, meaningfulness (measured by the number of realistic items a polygon reminded subjects of), and colour of the polygons were manipulated for preference. Results suggested that complexity, when compared to other variables included, only accounted to a small variation in preference. Moreover, meaningfulness demonstrated a larger role than complexity when predicting preference. However, as the authors stated, the number of associations of a polygon is not an uncontaminated measure of meaningfulness as it varies in ambiguity and tends to be subjective.

1.3.5 Fractal Dimension

Fractals are used in quantifying the complex structure exhibited by many natural patterns; they are typically self-similar patterns and exhibit across different spatial scales (Mandelbrot, 1983). Fractals consist of patterns that recur on finer and finer scales, building scale-invariant shapes of immense complexity; many of nature's patterns have been shown to be fractal (Taylor, Spehar, Donkelaar, & Hagerhall, 2011). As a result, a great number of studies emerged to investigate the relationship between a pattern's fractal character and its visual properties (Taylor et al., 2011). However, only a few focused exclusively on the linkages between fractals and preference. Taylor (2003) conducted a number of perception studies focusing on human's preference on fractal and non-fractal images. Out of 120 participants, 113 preferred examples of fractal patterns over non-fractal patterns.

Fractal patterns can be quantified using the parameter called fractal dimension, D. As identified by Mandelbrot (1983), this parameter refers to the measurement of the fractal scaling relationship between the patterns at different magnifications. The D value lies between 1 and 2; a smooth line with no fractal structure has a value of 1 and a filled area has a value of 2. This parameter was used in many experiment investigating fractals' aesthetic values. Sprott (1993) was the first to conduct experiments on the aesthetics of fractals and concluded that fractals with D values ranging from 1.1 to 1.5 was seen as most attractive.

A more recent experiment conducted by Sephar, Clifford, Newell & Taylor (2003) found similar results, in which subjects displayed a consistent aesthetic preference for fractal images, regardless of whether these images are generated by nature, by mathematics, or by the human hand. The stimuli set used included natural fractals, mathematical fractals, and human fractals; all stimuli were digitised and scaled to identical geometrical dimensions and presented in achromatic mode. Natural scenes with D values ranging from 1.1 to 1.9 were used in the first category. The second category included computer generated images of simulated coastlines with D values ranging from 1.33 to 1.66. For the category of human fractals, cropped images from Jackson Pollock's paintings, with D values ranging from 1.12 to 1.89 were used. Visual preference was determined using a forced-choice method of paired comparison; participants indicated their aesthetic preference between the two images appearing next to each other on a monitor. These comparison groups consisted of fractal images with either identical or different D values. Results revealed a consistent trend for aesthetic preference to peak within the D values ranging from 1.3 to 1.5 for the three distinctly different categories. Furthermore, the results demonstrate three ranges with respect to aesthetic preference for fractal dimension: 1.2 to 1.1 as low preference, 1.3 to 1.5 as high preference, and 1.6 to 1.9 as low preference. An inverted U-shaped relationship was found between fractal dimension and aesthetic preference. Again, this relationship traces back to the Wundt Curve discussed by Berlyne (1958, 1963), in which that preference for any stimulus is determined by its arousal potential.

One possible explanation for such preference as proposed by Taylor et al. (2011) is that the human eye traces out fractal patterns characterized by D from 1.4 to 1.5 when in search mode. An alternative explanation is based on familiarity as many of nature's fractals cluster around D value of 1.3, perhaps the constant exposure to mid-ranged fractals in nature helped in forming human's preference for fractal patterns within this category (Aks & Sprott, 1996).

Fractals have also been used for the study of perception, particularly in linking fractals to psychophysics and personality traits (Mitina & Abraham, 2003). Data collected suggested a trend to rate fractals with higher range in D value as more aesthetically attractive and complex. Furthermore, subjects with prevailing modesty, tactfulness and pliability displayed this trend more prominently than their peers. Results from these prior experiments have suggested an inverted U-shaped relationship between fractal dimension and aesthetic preference.

1.3.6 Balance

Balance is a fundamental feature that contributes to the organizational structure of an aesthetic visual image. The organizational structure of a visual image plays an important role in how the image is being perceived. According to Wilson & Chatterjee (2005), preference for content is likely to be shaped by cultural differences, whereas preference for form is likely to be influenced by structural features such as dynamic balance. They defined dynamic balance as the way in which unrelated elements of an image produce visual forces that compensate for each other, so a sense of coherence and unity can be achieved. Wilson & Chatterjee (2005) developed a method to create stimuli in which balance can be quantified, which is referred to as the assessment of preference for balance (APB). A total of 216 images were created on the computer with equal number of circles, squares, and hexagons; balance scores for each stimulus were calculated. Stimuli produced covered a range of balance scores from 3.6% (balanced) to 65.9% (imbalanced). Subjects were required to judge the overall sense of balance of each image first, followed by rating each image based on personal preference. A follow-up study was conducted, in which subjects rated the images by personal preference first followed by rating each image based on balance characteristics. Results indicated that the objective balance scores accounted for 73% and 78% of the variance in subjective preferences for the images. Moreover, designs with circles were preferred the most, followed by hexagons; squares were preferred least. Similar regression slopes were found in images with circles and hexagons, indicating that the objective parameters of balance have influence on preference. However, the relationship between balance and preferences for images with squares was found to be non-linear.

1.3.7 Size

Substantial research reveal that size plays an important role in judgement processes in both animals and humans (Silvera, Josephs, & Giesler, 2002). Existing research indicates that preference of shapes is strongly biased towards large stimuli material (Martin, 1906; Martindale et al., 1990; Silvera et al., 2002). Martin (1906) found an inverted-U shaped relationship between size and preference; preference ratings were provided for circles ranging in size from 1 mm to 500 mm. However, Martindale et al. (1990) criticized this finding as they believe that the size of the border surrounding the circles confounded the size of the actual stimulus.

Several studies led by Martindale et al. (1990) found that preference was positively related to size in a linear fashion. However, a number of other variables including number of turns, typicality, and colour were also included in the analysis. In one of the experiments, an interaction effect of size and number of turns was also significant, where less complex polygons in larger sizes were more preferred and more complex polygons in larger sizes were less preferred. In this case, number of turns accounted for 87.3% of the variance and size accounted for 1.3%. Size was generally related to preference in a monotonic trend where preference increased as the size of the stimuli increased.

A series of experiments conducted by Silvera, Josephs, & Giesler (2002) found a preference for larger stimuli with both adult and three-year-old participants. Four studies were conducted in which subjects were asked to make preference judgements among pairs of two-dimensional stimuli that varied in size and informational complexity; stimuli pairs included abstract shapes, alphanumeric characters, and Chinese characters. 130 different stimuli ranging in size from 0.56 to 97.5 square inches were used. Participants viewed a pair of stimuli at the time and were forced to make a choice based on preference. Results revealed that the larger stimulus object was preferred significantly more often than would be expected by chance by adults and three-year-old participants. However, possible preference confounds could be present; for example, it is possible that some characteristic of familiar symbols such as the letters in the standard American alphabet are processed differently than unfamiliar symbols. This problem was addressed in study

2 by using a different and novel set of stimulus objects composed of Chinese characters. All participants of study 2 did not have any prior knowledge of the Chinese language. Results from study 2, again, demonstrated that larger objects were preferred significantly more over smaller objects. Study 3 was conducted to examine the role of semantic content in the association between size and preference. Participants were randomly assigned either to the perceptual condition which used the same procedure used in study 1 or to a conceptual condition. In the conceptual condition, participants were asked to generate a meaning for each member of each stimulus pair and then indicate which object they preferred. Results confirm that in both conditions, participants preferred large over small stimulus objects. In other words, preference-evoking aspects of the stimuli dominated over semantic content of the stimuli. In study 4, participants were presented with eight pairs of geometric/alphanumeric shapes and eight pairs of Holtzman inkblots. Holtzman inkblots were used to eliminate the size-preference relation by having the participants generating meanings independent of the influence of physical size. In addition, attentional load was manipulated by assigning participants to two conditions. The high load condition required the participants to respond as soon as possible for each stimulus pair. In the low load condition, participants had 20 seconds to judge each stimulus pair. Results reveal that cognitive load had a larger impact on preferences for large stimuli with the inkblots than with the alphanumeric/geometric stimuli. There was also a significant preference for large stimulus objects for alphanumeric/geometric stimuli than for inkblots. In other words, size-based preference effect can only be eliminated by using stimuli specifically designed to evoke content-based meanings under conditions of low attentional load.

1.4 Research Theme and Objectives

The body of work presented here focuses on finding ways to mitigate the conflict between aesthetic quality and the demand on forest resources. Two experiments focus on defining shape as a visual quality indicator while relating it to public perception and preference. Results from these experiments provide insightful information to forest designers pertaining to public aesthetic preference choices. Moreover, this body of work helps in opening doors to future research in the field of landscape esthetics by drawing parallels between various disciplines.

The objectives of the research are fivefold.

1. Review existing visual preference indicators through literature analysis
    a. What are the key findings regarding visual preference indicators in the field of landscape esthetics?
    b. What are the key findings regarding visual preference indicators in the field of psychology?
    c. Can parallels be drawn from these two disciplines?

2. Determine what aspects of shape can influence perception and preference, in both landscape aesthetics and psychology
    a. How is shape used in existing research with respect to preference?
    b. What characteristics of shape predict preference?

3. Quantify the effects of shape characteristics on aesthetic preferences

a. How were they quantified and measured in both disciplines? Can parallels be drawn from one to the other?
b. To what extent can these characteristics affect preferences?

4. Investigate the effects of contexts (of shape) on aesthetic preferences
   a. Could context (harvests vs. shapes) be a predictor of preference?
   b. If yes, could there be a link between context and area of study with respect to preference (academic background)?

5. Investigate the importance of the aerial view
   a. Can the effects of shape be extended to the aerial view?
   b. Should current visual resource management expand to include the aerial view?

1.5 Research Structure

The first and last chapter of this thesis provide context for the main body of research presented. The initial chapter opened by stating the importance of aesthetics in the study of landscapes. This chapter also presents a literature review focusing on three topics: visual quality indicators, harvest block design, and shape perception and preference. The concluding chapter summarizes the main findings of this research, makes implications for forest designers and managers on improving aesthetic quality, and provides inferences for future research in this area.

Chapter 2 presents the first experiment, which investigated the effects of complexity and context on individual aesthetic preference in the aerial view. Furthermore, subjects were asked whether or not they agree with the inclusion of the aerial view to VRM. Order and area of study were also tested for significance. This chapter has been submitted for peer-review in an academic journal.

Chapter 3 presents the second experiment, which focused on identifying and quantifying the effects of shape characteristics have on aesthetic preference. In addition to context, angularity, edge number, edge angle, and intrusion were manipulated. Along with the computer ratings of the two image sets, a poster ranking task was also completed by each subject.

Chapter 2: Relating Shape to Human Aesthetic Evaluations from an Aerial Perspective

2.1 Introduction

Shape is a potential indicator of preference in regards to aesthetic evaluations of the landscape, particularly in the design of harvest blocks. Studies on the perceptual effects of harvest block design have found a strong preference for circular harvest blocks with medium to high levels of complexity (Chamberlain & Meitner, 2012). However, limited empirical evidence exists on defining what characteristics of shape can influence aesthetic preference and to what degree. Furthermore, the majority of perception-based research in the field of landscape aesthetics has focused on the perspective view. We intend to fill this gap by investigating the perceptual effects of two main shape characteristics in the aerial view of a landscape: context and shape complexity.

2.2 Background and Objectives

Numerous studies have focused on relating visual quality elements of the landscape to individual aesthetics perception and preference. One important visual indicator of preference in forested landscapes is the percentage of visible alteration; landscapes with a low percentage of human modification are perceived as most acceptable (B.C. Ministry of Forests, 1996, 1997b; Paquet & Belanger, 1997). Green-tree retention levels and patterns have been found to be critical in relation to perceived scenic beauty; higher preference was associated with increased retention level only with dispersed retention pattern (Ribe, 2005, 2009). Furthermore, all levels of aggregated retention demonstrated low preference.

Another key finding that emerged from perception-based aesthetics research is the concept of naturalness, defined as the relation of how close a landscape is to a preconceived natural state (Tveit et al., 2006). The naturalness of a landscape is also related to the percentage of visible human alteration, unmanaged landscapes are more likely to be perceived as natural. A number of environmental psychologists have identified naturalness as a key aspect of visual quality (Gobster, 1999; Kaplan & Kaplan, 1989; Purcell & Lamb, 1998; Ulrich, 1979). Ode et al. (2009) have furthered confirmed the relationship between landscape preference and naturalness. Three indicators of naturalness, including level of succession, number of woodland patches and shape index of edges, were explored and demonstrated significance. Fractal dimension (fractured shapes possessing repeating patterns when viewed at increasingly fine magnifications), as another indicator of naturalness, could provide part of the explanation to the relationship between preference and naturalness (Hagerhall et al., 2004; Spehar et al., 2003). Studies have also revealed that there is a preference for half-open landscapes over very open landscapes and closed ones (Tveit, 2009), supporting both the prospect-refuge theory (Appleton, 1996) and the information processing theory (Kaplan & Kaplan, 1989).

The development of visual landscape indicators was initiated in the early 1970s (Tveit et al., 2006). Kaplan & Kaplan (1989) have established a seminal theoretical framework for the aesthetic experience of landscape based on four key concepts, including complexity, coherence, legibility and mystery. Tveit et al. (2006) proposed a theory-based framework to effectively analyze visual characters of a landscape based on nine key visual concepts, including stewardship, coherence, disturbance, historicity, visual scale, image ability, complexity, naturalness and ephemera. Recent efforts have expanded the existing framework by integrating the experience-based complexity through the use of three dimensions, including the distribution of landscape elements, spatial organisation of patterns, and variation and shape of elements and patterns (Ode, Tveit, & Fry, 2008; Ode, Hagerhall, & Sang, 2010). However, research investigating these concepts is still lacking.

The design of harvest blocks can be effective at increasing perceived scenic beauty in the landscape, in background and deeper middle-ground distances from observers (Karjalainen & Komulainen, 1999; Ribe, 2002, 2005). Moreover, naturalistic harvest block design can have an effect on preference when harvests are few in number (Palmer, Shannon, Harrilchak, Kokx, & Gobster, 1995; Paquet & Belanger, 1997). Recent studies led by Chamberlain & Meitner (2012) focusing on shape perception and preference in the context of harvest block design have revealed a number of interesting findings. Circular shapes with smooth undulating edges were preferred over blocky angular shapes. Individuals also preferred shapes with medium or high levels of complexity compared to harvest shapes of lower visual complexity. There was also a strong preference for small percent alterations to the landscape; preference decreased significantly as percent alteration increased. The results from these studies demonstrate that the shape of a harvest block may, in fact, impact the overall aesthetic of the landscape contrary to the literature to date (Ode, Fry, Tveit, Messager, & Miller, 2009; Ribe, 2005).

In order to fully understand visual indicators and their relationship to aesthetic perception, we must thoroughly investigate their effects in all spatial forms. The majority of perception-based research in the field landscape aesthetics has focused on the perspective view. However, all landscapes, whether modified or not, can be seen from airplanes, remotely-sensed data and widely published photographs (Ribe, 2005).There seems to be a lack of research exploring how visual indicators can influence perceived scenic beauty from an aerial perspective. Even though visual management of forests is often based on perspective viewpoints, it is also fairly common today to view forests from the air while in a plane or online using programs, such as Google Earth. As a result, this research investigates the effects of harvest block design from the aerial perspective and attempts to determine the degree to which participants felt that visual forest protection should expand to include aerial views.

Research on the perception of shapes has been carried out in the field of psychology. Both methods and results can provide valuable insights in finding the relationship between harvest block design and preference in the context of forestry. Results from a number of experiments suggest that preference for shape depends on various features including complexity, angularity, symmetry and size. An inverted U shape relationship between complexity and preference has been found in various experiments; people generally preferred medium levels of complexity (e.g. number of sides in a polygon) when compared to low and high levels (Attneave, 1957; Berlyne, 1958, 1963; Day, 1967). Contrary to these findings, Martindale, Moore & Borkum (1990) concluded that preference was related to the number of turns in a polygon by monotonic rather than inverted-U functions. When considering the contour of the shape, people tend to like curved forms significantly more than shapes with an angular contour. Many argue that this bias stems from an increased sense of threat and danger conveyed by sharp visual elements (Bar & Neta, 2006, 2007; Larson, Aronoff, Sarinopoulos, & Zhu, 2008; Larson et al., 2007; Silvia & Barona, 2009). Similar preference for curved shapes was also found in product design (Westerman et al., 2012). Various studies indicate that preference of shapes is strongly biased towards axes of global symmetry (Eisenman & Gellens, 1968; Eisenman, 1967a, 1967b; Palmer, 1985). Moreover, bilaterally symmetrical patterns, those which have their axis of symmetry vertical are more saliently symmetrical than patterns with axis of symmetry at another orientation (Wenderoth, 1994). Recent studies have also found a tendency to rate large stimuli material as more favourable (Silvera et al., 2002). In addition, they concluded that this size-based preference effect can only be eliminated by using stimuli specifically designed to evoke content-based meanings under conditions of low attentional load. This finding is consistent with results from landscape preference studies; when shapes were presented as harvest blocks, preference level decreased as size of the harvest block increased (B.C. Ministry of Forests, 1996, 1997b; Paquet & Belanger, 1997). This indicates that context associated with the shape could have impacts on participants' preference ratings. Context, in this case, refers to the content represented by the shape; its perceptual effect has yet to be systematically explored. A number of experiments have focused on relating prototypically and meaningfulness to preference. Meaningfulness, defined as the number of realistic items a polygon reminded subjects of, was found to be a significant predictor (Martindale et al., 1990, 1988; Martindale & Moore, 1988, 1989).,Prototypically of shape, was also found to help explain preference.

These experiments focused exclusively on shapes in their most basic form, as black shapes on white backgrounds. In other words, the practical applicability of these results to harvest block design must be verified. Thus, the primary objective of this study is to investigate whether the presentation of shapes in different contexts would affect subject preference ratings. Secondly, this research attempts to establish whether the complexity of the shape itself as seen from an aerial view affects aesthetic judgments, as demonstrated in previous studies (Chamberlain & Meitner, 2012). The experiment presented in this paper extends work by examining manipulations of shape presented in different context (harvests vs. shapes), as well as in terms of complexity (low, medium, high) from the aerial perspective.

2.3 Method

2.3.1 Stimuli – Image Sets

The graphical component of the experimental interface consisted of the two image sets shown in Figures 1 & 2. The first set included aerial images of harvest blocks in British Columbia extracted using Google Earth. A total of 160 harvest blocks were collected to ensure a broad range of variety in the design. These were then analyzed using FRAGSTATS, a spatial pattern analysis programs used for quantifying landscape structure (McGarigal & Marks, 1995). Both area and shape metrics were used to analyze these harvest blocks (see Appendix 1 for detailed descriptions for each metric). Area metrics used include: AREA (patch area), PERIM (patch perimeter) and GYRATE (radius of gyration). Shape metrics used include: PARA (perimeter-area ratio), SHAPE (shape index), FRAC (fractal dimension index), LINEAR (linearity index), CIRCLE (related circumscribing circle) and CONTIG (contiguity index).

After careful consideration, shape index was used to indicate complexity level since this metric was easily understandable both visually and perceptually. SHAPE is calculated as patch perimeter (given in number of cell surfaces) divided by the minimum perimeter (given in number of cell surfaces) possible for a maximally compact patch (in a square raster format) of the corresponding patch area (McGarigal, Cushman, Neel, & Ene, 2002). The shape index measures the complexity of patch shape compared to a standard shape; in this case, SHAPE was evaluated by adjusting for a square (or almost square) standard as raster images were used. For instance, a square has a shape index of 1; the shape index value increases as complexity of the shape increases. This shape index metric is widely applicable and used in landscape ecological research (Forman & Gordan, 1986 as cited in McGarigal & Marks, 1995).

Harvest blocks analyzed by shape index ranged from 1.20 to 3.97 in value. Harvest blocks were then grouped into three categories based on this range: low-shape complexity (R=1.20-1.83, $\bar{x}$ =1.53, SD=0.21), medium-shape complexity (R=1.86-2.44, $\bar{x}$ =2.07, SD=0.17), and high-shape complexity (R=2.45-3.97, $\bar{x}$ =3.06, SD=0.48). Fifteen harvest blocks were randomly selected from each category, resulting in 45 harvest blocks for the first image set. The resolution of these images remained the same; however, thesize of each harvest block was altered to ensure the same visual percent alteration on screen among all 45 images. The second image set was based on the same 45 harvest blocks as image set 1; only the shape was kept constant, all other landscape characteristics were eliminated. Each aerial harvest block was outlined and filled in as a black shape on white background using Adobe Photoshop.

Figure 1 Images from image set 1 – harvest blocks in aerial view (low, medium, high complexity)

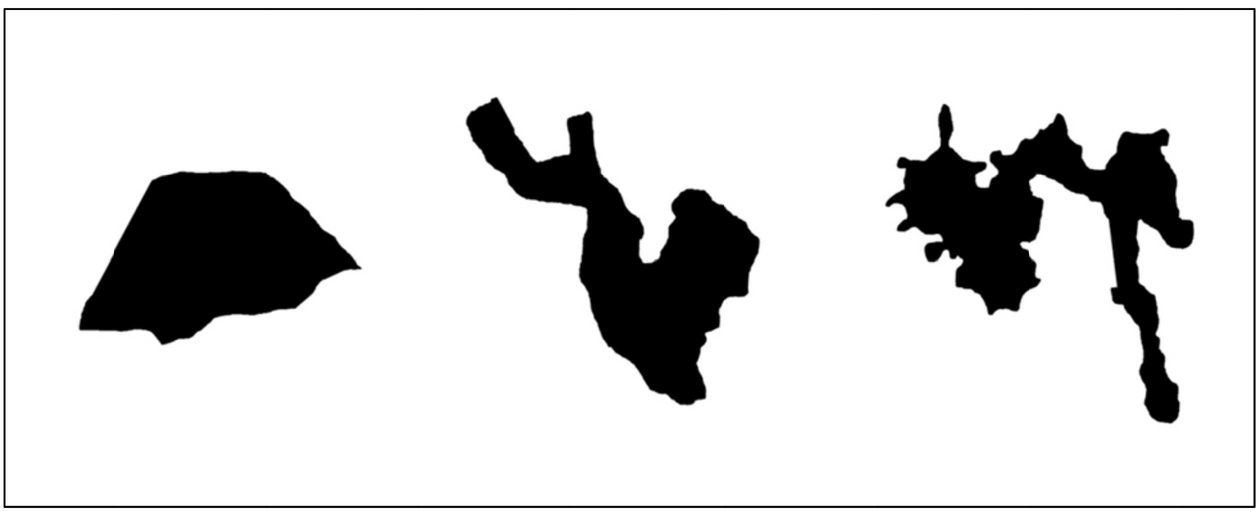


Figure 2 Images from image set 2 – black shapes on white backgrounds (low, medium, high complexity)

2.3.2 Design

This experiment used a 2 (order: shown harvest images first vs. shown shape images first) x 2 (context: harvests vs. shapes) x 2 (area of study: non-environmental focus vs. environmental focus) x 3 (shape complexity: low, medium, high) design. Context and complexity were within-subjects variables. Order and study area were between-subjects variables. Gender was originally included in the design, but was not statistically significant so it was removed.

Subjects were divided into two groups based on their academic background: environmentally focused and non-environmentally focused in their academic disciplines. Subjects with disciplines in arts (music, psychology, philosophy, and history), sciences (biology, chemistry, and physics), applied sciences (engineering, architecture), medical sciences (pharmacy, veterinary), health sciences (kinesiology), and commerce (business, economics) were placed in the non-environmentally focused group. Subjects with academic backgrounds in forestry, natural resources, conservation, wood science, and environmental studies were considered to be environmentally focused.

2.3.3 Hypotheses

The four variables explored in this study were: context, order, complexity and study area. With respect to context, we predict that preference ratings will depend on the context (harvests vs. shape) the shape was presented in. We also believe that this context effect should be more pronounced when considering subjects' area of study. In terms of shape complexity, we expect higher preference ratings for shapes with medium levels of complexity. The effect of order should demonstrate no significance with respect to preference ratings.

2.3.4 Participants

Seven-five University of British Columbia students, 38 female and 37 male, with ages ranging from 19-43 years (Female: $\bar{x}$= 25.18, SD = 4.90; Male: $\bar{x}$= 25.92, SD = 4.95), participated in the experiment for monetary compensation. All had normal or corrected-to-normal vision. Informed written consent was obtained from each participant prior to the experiment.

2.3.5 Procedure

Each subject participated individually and was randomly assigned to an order condition; either to view image set 1 first or image set 2 first. Nine sample images were shown prior to the actual image set to provide the subjects with the range of designs that they were to encounter in order to anchor their use of the rating scale and to avoid scale compression issues, as well as to familiarize them with the experiment interface. Images from both image sets were presented sequentially in a different random order for each subject with no time limit for response, and subjects were required to rate each image for preference on a 1-10 scale (1=least preferred, 10=most preferred). After the ratings of the two image sets, subjects were required to complete a follow-up demographic information questionnaire.

2.3.6 Analysis

Preference ratings were analyzed using a repeated measures analysis of variance (ANOVA). One subject was removed from the analysis as this subject used 5 as the rating for all images in image set 2 (shape) and therefore gave no meaningful data. In the statistical analysis, the assumption of sphericity was not satisfied; therefore, the null hypothesis that the error covariance matrix is proportional to an identity matrix was rejected. As a result, the ‘Greenhouse-Geisser’ correction was used.

2.4 Results

2.4.1 Computer Ratings

The analysis revealed five statistically significant characteristics relating to shape perception that affected individual preferences (Table 1).

Table 1 ANOVA repeated measure results of shape attributes on preference ratings

Variable	df	Mean square	*F* ratio	*p*	Eta^2
Shape complexity	1.551	1751.426	142.782	0.000*	0.115
Context	1	26.669	8.542	0.004*	0.008
Area of study	1	33.078	5.007	0.025*	0.005
Shape complexity × context	1.838	87.796	22.166	0.000*	0.020
Shape complexity × area of study	1.551	1053.440	85.880	0.000*	0.072
Error (shape complexity)	1708.712	12.266			
Error (context)	1102	3.122			
Error (area of study)	1102	6.606			

* Statistically significant results at the p = 0.05 level.

The effect of order was insignificant, indicating that the order of seeing image set 1 first or image set 2 first did not influence participants’ preference ratings.

When considering the effects of shape manipulations on individual preferences, there was a main effect of shape complexity, F (1.551, 1708.712) = 142.782, p < .000, $Eta^2 = .115$, such that participants preferred designs with high complexity, followed by medium complexity, and, lastly, designs with low levels of complexity. Figure 3 illustrates the mean ratings for each level of complexity. Designs with low levels of complexity were less preferred than those with high levels of complexity (by 25% difference). Mean ratings for high complexity designs were the highest; however, the difference in mean ratings from a medium level of complexity to a high level of complexity is insignificant as indicated by the error bars.

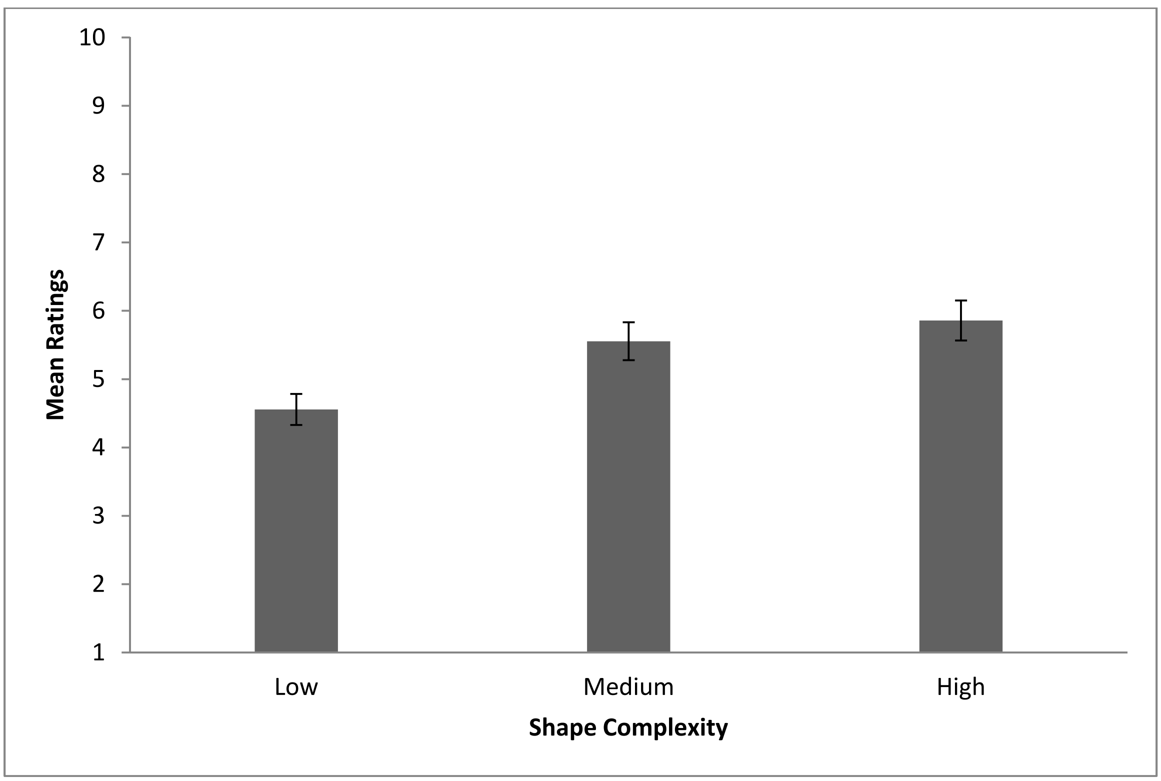


Figure 3 Relationship of mean ratings with shape complexity

There was also a main effect of context, $F(1, 1102) = 8.542$, $p < .004$, $Eta^2 = .008$ (Figure 4), such that participants rated the shape image set higher than the harvest image set. The shape version was rated higher than the harvest version of the same design. However, the difference for preference between the two is small (less than 2%).

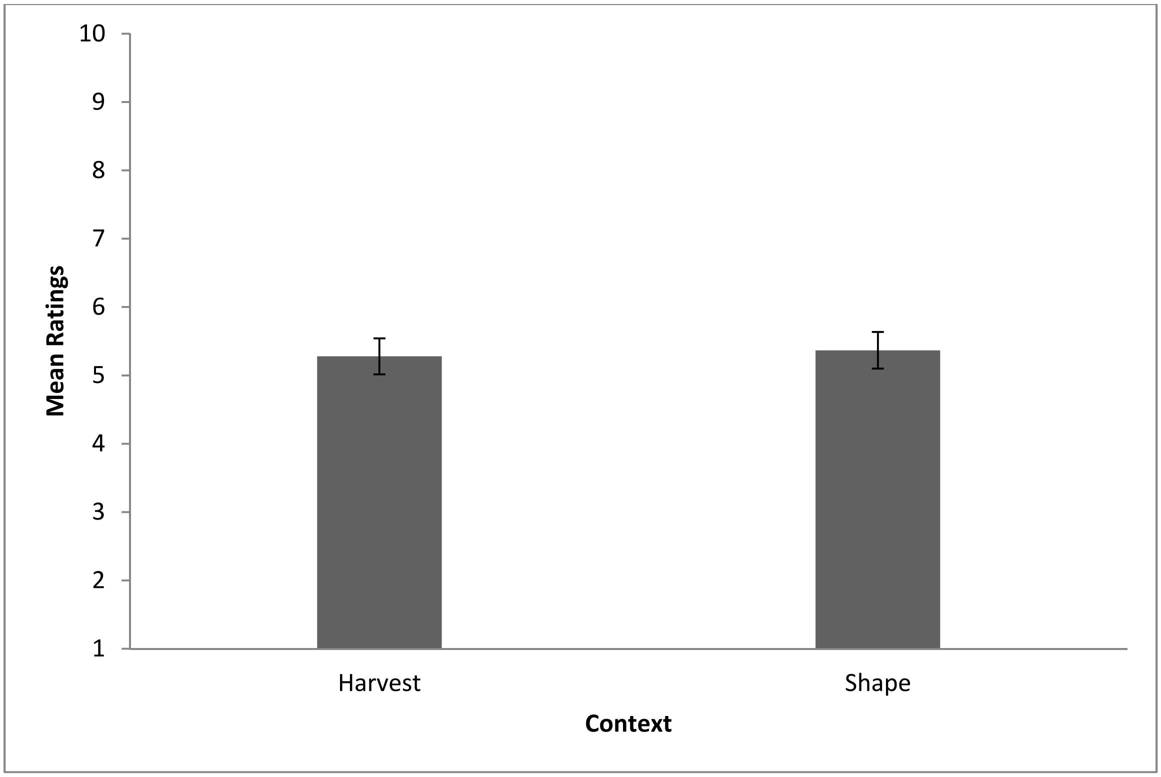


Figure 4 Relationship of mean ratings with context

The interaction between shape complexity and context was significant, F (1.838, 2025.596) = 22.166, $p < .000$, $Eta^2 = .020$ (Figure 5), indicating that harvest images with low complexity were rated lower in preference (10%) than those from the shape image set. However, Tukey's HSD test revealed that under the medium complexity level, the difference in ratings between harvest and shape was not significant. Furthermore, ratings of designs with medium and high complexity were not significantly different under the shape condition. The difference between harvest and shape designs with high complexity demonstrated significance. Interestingly, images with high complexity were more preferred than shape images with the same complexity level (by 5%).

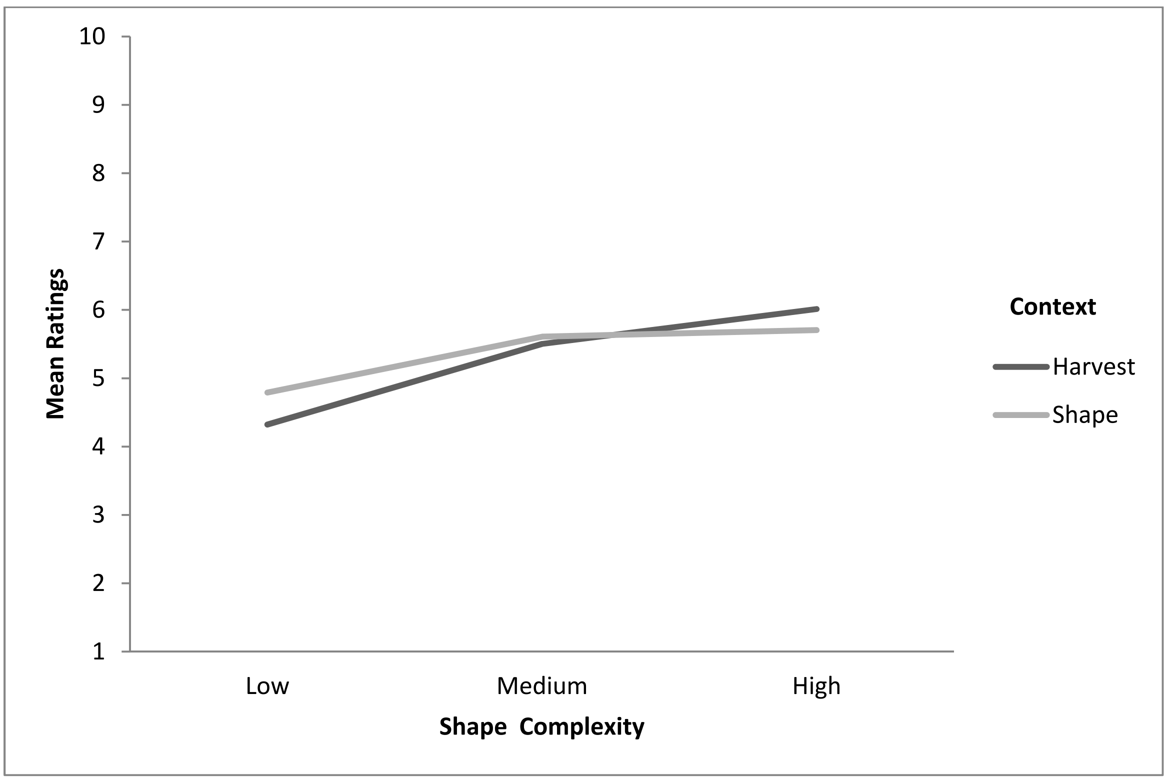


Figure 5 Interaction effect of shape complexity and context: mean ratings of the three levels of complexity for context (harvest vs. shape)

There was a main effect of area of study, $F(1, 1102) = 5.007$, $p < .024$, $Eta^2 = .005$ (Figure 6), such that rating means of participants with non-environmental backgrounds were higher in preference (2%) than more environmentally- focused participants. However, the effect size is small.

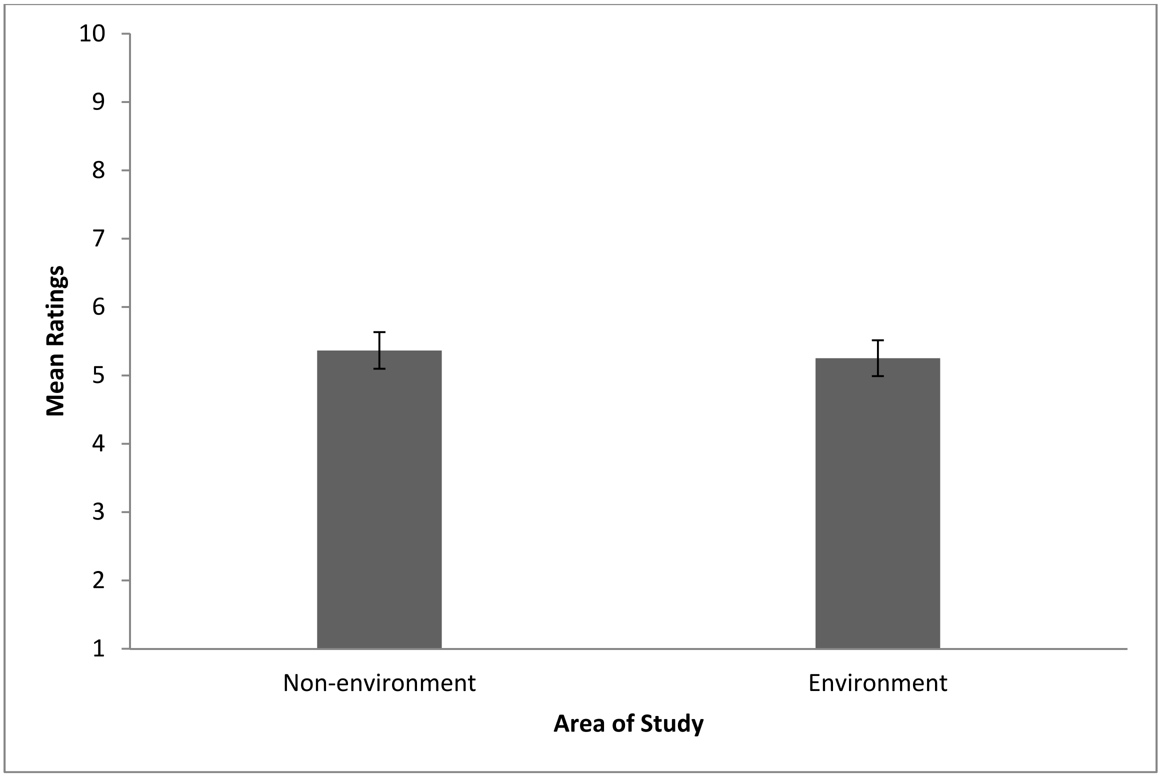


Figure 6 Relationship of mean ratings with area of study

The interaction effect between shape complexity and area of study was also significant, F (1.551, 1708.712) = 85.880, $p < .000$, $Eta^2 = .072$ (Figure 7). Participants studying environmental topics demonstrated the complexity effect more prominently. This means that, as complexity levels increased, preference ratings also increased. In contrast, non-environmentally focused participants preferred images with medium complexity and the mean ratings for three levels of complexity were very similar (low=5.1, medium=5.6, high=5.5). Tukey's HSD test indicated that under the medium complexity level, study area did not have a significant effect. Moreover, preference ratings produced by students with non-environment focuses demonstrated no significant difference between designs with medium and high levels of complexity.

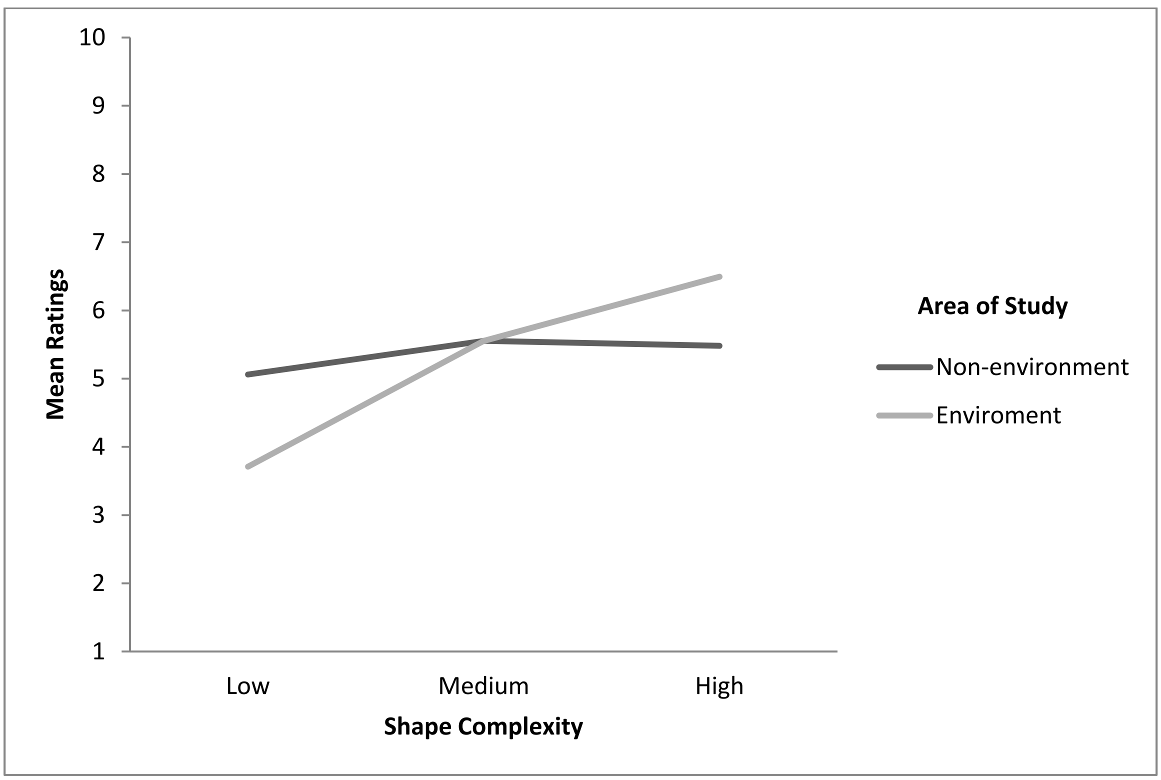


Figure 7 Interaction effect of shape complexity and area of study: mean ratings of the three levels of complexity for study area (non-environment focused disciplines vs. environment focused disciplines)

2.4.2 Expansion to Include Aerial View in VRM

58 out of 75 (77%) participants selected yes to the question “Our question is whether or not you feel that it would make sense to expand our visual management of the forest to include this new aerial view”.

2.5 Discussion and Conclusions

In this experiment, the effects of preference for shape were examined in the context of forest harvest patterns. Main effects were observed for shape complexity, context, and study area. Moreover, the interaction of shape complexity and context, as well as shape complexity and area of study were statistically significant. One of the objectives of this study was to determine the subjects’ opinions on the inclusion of the aerial view in forest visual management. We asked the subjects whether or not forest managers should expand visual management of the forest to include an aerial view. The majority (77%) agreed that forest managers should include the aerial perspective when planning for visual impacts. Although this finding is solely based on subjects’ opinions and cannot dictate a comprehensive conclusion, it certainly warrants further investigation.

The results indicate that complexity of the shape had the largest effect on preference for harvest design of the four variables tested. As discussed in the literature, complexity, a characteristic of shape, seems to be a factor in ascertaining aesthetic judgements of shapes (Berlyne, 1958, 1963; Chamberlain & Meitner, 2012; Day, 1967; Martindale et al., 1990). An experiment conducted by Day (1967) investigated subjects’ ratings on a series of random-shaped polygons varying in number of sides ranging from four to 160. He concluded that subjective evaluations of pleasinngess peaked at 6-sided and 28-sided levels then significantly decreased with increased complexity. Similar experiments done by Martindale et al. (1990) found comparable results and concluded that number of turns in a polygon, indeed, is related to preference. However, they also argued that "number of turns is not an uncontaminated measure of complexity…may resemble pictures of real objects". Complexity should not and cannot be defined solely on the number of turns in a shape, especially in the context of harvest design. Recent research proposes that landscape complexity may be quantified using metrics within the framework of landscape ecology (Ode et al., 2010; Sang et al., 2008). Hence, a form of landscape patch metrics was used in this study to define complexity. The harvests used in this experiment were analyzed using the shape metrics in the FRAGSTATS program (McGarigal et al., 2002). Although the definition of complexity used in this study was developed within the framework of landscape ecology, some of the findings were comparable to those found in psychology experiments. The results confirmed that subjects' preference ratings rose with increases in shape complexity; however, a monotonic relationship between shape complexity and preference was prominent instead of the inverted U-shaped function as proposed by existing literature in psychology. This might be due to differences in the experimental design which only included three levels of complexity; it is unclear if parallels can be drawn with increased complexity levels in the context of harvest block shape. However, it is possible that preference will decrease if complexity levels were to increase, following the inverted U shape relationship discussed in the literature. Given that these shapes were directly sampled from actual harvest blocks that currently exist in British Columbia, it can be surmised that the level of shape complexity that actually exist is insufficient to reach this threshold of reversed preference. This means that, for all intents and purposes, increased complexity in harvest block design in the context of forest management can typically be seen as a positive aesthetic variable so long as a reasonable limit is placed on the upper end of complexity of shape.

The shape image set was rated higher in preference than harvest image set by only 2% of difference. The reasoning behind this finding is unclear. Perhaps the shape image set is simpler with less distracting elements in each image, whereas images from the harvest set comprised several elements such as colour, texture, form, and edge. It is also possible that the two image sets created a reversal effect in figure-ground perception. For instance, the black shape (in shape image set) can be perceived as the figure with the white space as the background. However in the harvest condition, a perceived reversal between the figure and background could have occurred resulting in lower preference ratings. Another possible explanation is that harvest blocks, particularly clear-cuts are generally perceived negatively by the public (Bliss, 2000; Chamberlain & Meitner, 2012; B.C. Ministry of Forests, 1996; Sheppard, 2004).

An interaction of shape complexity and context was also observed. Results indicated that shape complexity had a stronger effect on preference ratings in the harvest condition than in the shape condition. In other words, participants were more sensitive to the complexity of harvest block design as opposed to the design of shapes. As demonstrated by the results, one can predict that the shape of the inverted U relationship for the two conditions would be different. In the context of harvest block designs, participants showed a lower preference for low complexity and a higher tolerance for greater complexity when compared to the shape condition. The results from the shape condition exhibit a flatter inverted U relationship overall; the threshold in preference for increased complexity seems to be lower in comparison. The reason behind such a result may be that high complexity shapes in a forestry setting are seen as organic and natural, whereas highly complex shapes on paper may be perceived as complicated and unpleasant. Moreover, previous studies revealed that people prefer more undulated and organic looking shapes in a natural setting (Bell, 2001; Chamberlain & Meitner, 2012).

The study also showed the influence that the subjects' area of study (academic background) had on their preference ratings. Subjects were identified either as environmentally-focused or non-environmentally focused in their academic disciplines. Mean ratings provided by environmentally focused subjects were lower than subjects focusing on non-environmental fields by 2% difference. However, mean ratings of both groups differed significantly when levels of shape complexity was added, indicating an interaction effect between shape complexity and area of study. Preference ratings of environmentally focused subjects increased as shape complexity level increased, whereas subjects focusing on non-environment related fields preferred medium complexity over both low and high levels of complexity. Major distinctions between mean ratings of the two groups can be found at low and high levels of complexity. This outcome is likely a reflection of subjects' areas of study. Participants in environmental disciplines perhaps had a greater chance to perceive low complexity shapes negatively as they potentially resemble clear-cuts and may be perceived as more disturbing to the existing landscape. In addition, highly complex shapes may have been perceived as more organic and natural, thus they were rated higher on the preference scale. Another finding worth mentioning is the number of outliers found within this group, who definitely influenced the overall mean ratings. Preference ratings provide by a small number of subjects suggested that these subjects preferred angular shapes with low complexity over circular shapes with medium or high complexity. Based on comments provided, the reasoning behind their ratings was that angular shapes were more pleasing to the eye due to their simple and organized form. Interestingly, these six subjects came from non-environmentally focused fields, including engineering and economics. This result may be a reflection of a possible link between preference ratings and educational training and it may be worthwhile to further explore these links between (particularly on academic backgrounds) in future studies.

The findings of this study suggest three additional issues that could be explored in future research. First, a set of complete and elaborate indicators of shape need to be developed. The consolidation of shape characteristics from both landscape aesthetics and visual psychology could provide a comprehensive review of shape. Existing literature has investigated other shape characteristics including symmetry, angularity and size (Bar & Neta, 2006, 2007; Eisenman & Gellens, 1968; Eisenman & Rappaport, 1967; Eisenman, 1967; Larson et al., 2008, 2007; Silvera et al., 2002; Silvia & Barona, 2009; Wenderoth, 1994; Westerman et al., 2012). However, no previous studies have examined these characteristics of shape all together; perhaps because of a lack of an extensive list of shape indicators. Second, the concept of complexity in shapes must be clearly defined; a unified definition is needed due to its broad applicability in fields such as ecology and psychology. Third, there is a need to draw parallels between current studies focusing on harvest shape designs with those shape experiments from psychology. Future studies need to be more interdisciplinary, predominantly in their methodologies; perhaps developing experimental methods addressing more than one discipline. Expansion of knowledge in these three areas may help to gain a better understanding in relating shapes to human aesthetic evaluations and to improve visual designs pertaining to harvest blocks.

The results of this study provide interesting findings that can be linked directly to the design of forest harvest blocks to achieve greater degrees of visual protection even when viewed from aerial views. Although it was not surprising to discover that complexity was the most influential variable predicting an individual's preference (even though this variable has been largely overlooked in the literature), the degree to which it played a role is intriguing. Complexity had the largest effect on subjects' preference ratings regardless of what context the shapes were presented in. Lastly, the overwhelming majority of subjects agreed (77%) that forest managers should consider including aerial views to current visual forest management strategies. While these results certainly brings with it a number of challenges, it serves as a reminder that times are changing and that people's opportunity and ability to view forests from the air have been dramatically increased. Visual forest protection today may only be realized when viewing the forest with our feet planted firmly on the ground, but that may not always be the case as the public increasingly starts to scrutinize forest management from the air.

Chapter 3: Quantifying the Effects of Shape Characteristics on Aesthetic Preferences

3.1 Introduction

The psychology of perception has a long history of studying how visual features influence aesthetic evaluation and preference. Research focusing on shapes in the field of psychology has proposed a number of predictors of preference including angularity, complexity, prototypically, symmetry, fractal dimension, and size. Shape has also been identified as a potential indicator of preference pertaining to aesthetic evaluations of the landscape, predominantly in the design of harvest blocks (Chamberlain & Meitner, 2012). But despite recent success in relating shape to preference of a perceived landscape, research in this area is still lacking. We intend to fill this gap by investigating the perceptual effects of context as well as four characteristics of shape: angularity, edge number, edge angle, and intrusion.

Research in both psychology and forestry has identified several characteristics of shape as potential indicators of preference. The effects of angularity and complexity have been investigated in both disciplines and consistency has been demonstrated through the results. However, a number of other potential preference indicators have not been fully investigated in the literature. There is a wide gap in directly linking these characteristics from one discipline to the other. As a result, a visual analysis of harvest block patterns was completed as part of this study. This task included the collection and investigation of harvest block images using Google Earth. A total of 160 harvest block images were collected to ensure a broad range of variety in the design. Along with angularity and edge number, two other distinct characteristics were found. We have noticed that all these harvest blocks can be visually sorted into two categories: “spiky” vs. “blocky”; “spiky” harvest blocks are those with reoccurring sharp edges and visually appear to be complex, and “blocky” harvest blocks are those with obtuse angled edges and generally resemble simple geometric shapes. We refer to this trend as edge angle; where the degree of the angles within a shape determines the overall look of the shape. Another distinct feature we noticed was that some of the harvest blocks had intrusions present, where one or more edges intrude into the shape itself. This is fairly common in harvesting practices as sometimes harvesting is performed near infrastructures such as roads. As a result, these two shape characteristics along with angularity and edge number were used in attempts to determine and quantify preference predictors in shape. Additionally, context – defined as the content represented by the shape – was also explored in this experiment.

Given such limited effort put in investigating the effects of shape within harvest block design; this research focused on relating shape to aesthetic preference and evaluation. Thus, the primary objective of this research was to establish and quantity potential shape characteristics affecting individual aesthetic preference. Secondly, this research attempted to investigate whether the presentation of shapes in different contexts could have an impact on preference ratings. The experiment presented in this paper expanded work in this area by analyzing manipulations of shape presented in different context (harvests vs. shapes), as well as in terms of angularity (angular vs. curved), edge number (low, medium, high), edge angle (acute vs. obtuse), and intrusion (with vs. without).

3.2 Method

3.2.1 Stimuli – Image Sets

The graphical component of the experimental interface consisted of two image sets shown in Figures 8 & 9. The first image set included computer generated polygons based on the following features: edge number, angularity, edge angle, and intrusion; resulting in 24 conditions (Figure 10). A total of 120 angular polygons were generated first using Adobe Illustrator; the same 120 polygons were then digitally rounded using Adobe Illustrator's "rounded corners[1]" function, allowing a comparison between preference for angular and curved versions of the same polygon. Four polygons were randomly selected from each condition, resulting in a total of 96 polygons used as image set 1 (shape). For image set 2 (harvest), the same 96 polygons were manipulated to resemble real harvest blocks using Adobe Photoshop.

[1] The "rounded corners" function in Adobe Illustrator allows the user to round the corners of shapes created, without compromising their overall shape. The curved version of all polygons used in this experiment used a radius of 100 point in the Rounded Corners function.

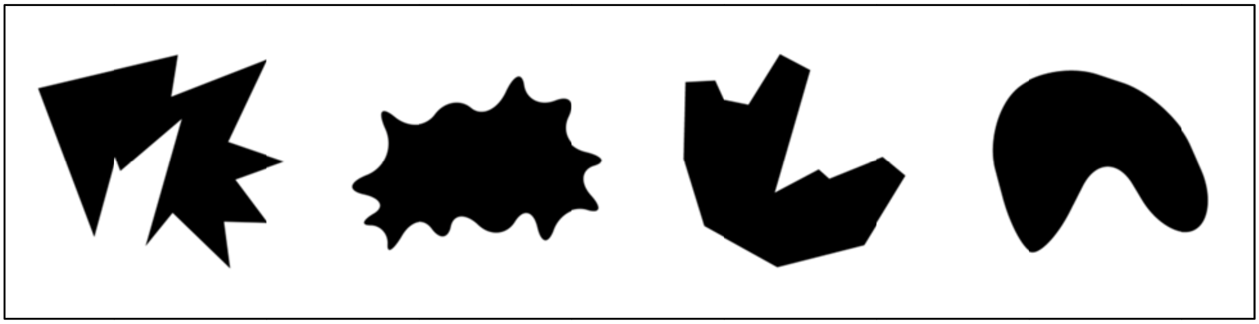


Figure 8 Examples of images from image set 1 (context: shape)

Figure 9 Examples of images from image set 2 (context: harvest blocks from the aerial perspective)

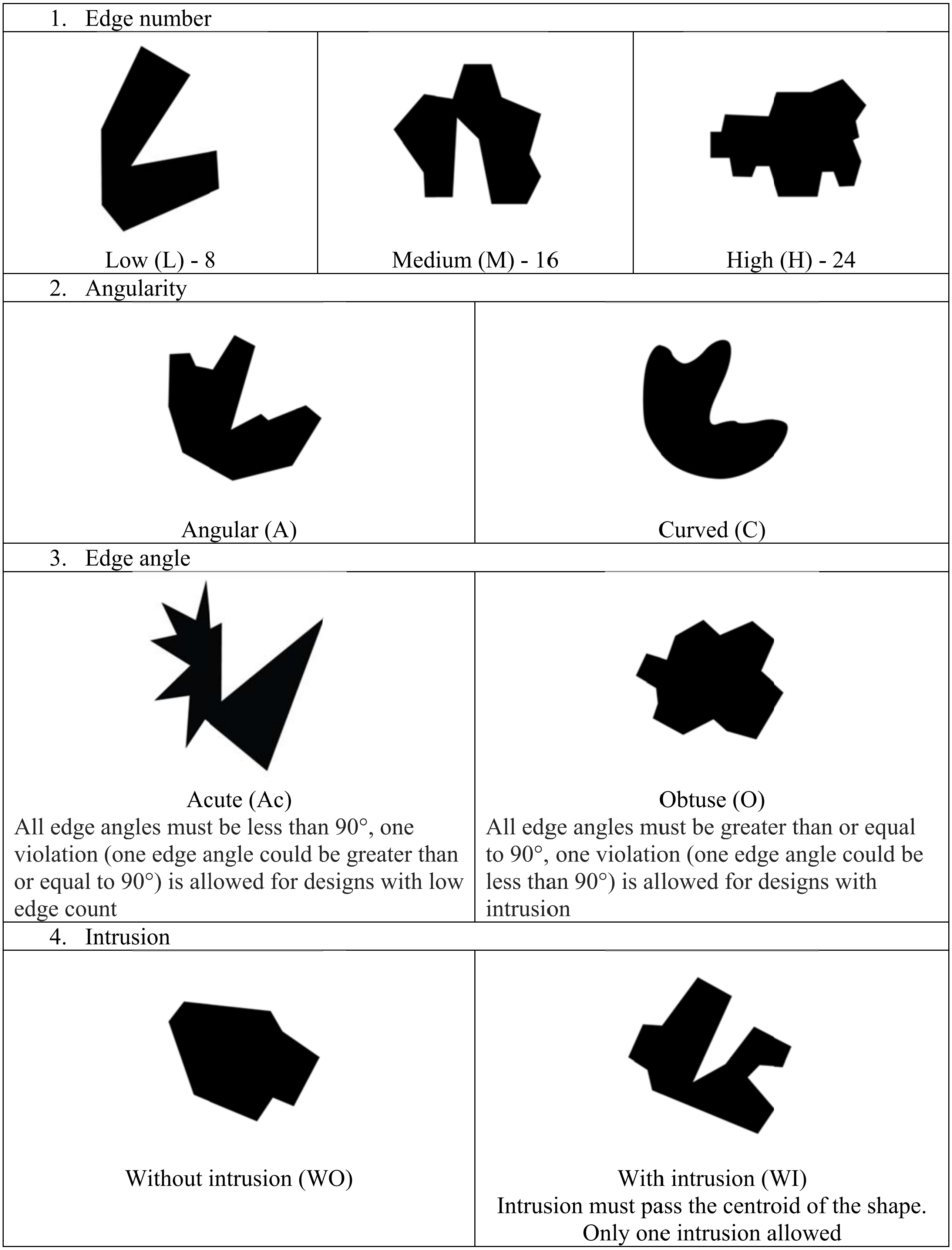


Figure 10 Features used for polygon computer generation

3.2.2 Stimuli – Poster

Posters were created for each image set; these were printed on 11x17” paper and used as part of the ranking task in the experiment. Each poster consisted of all 96 designs and four different versions were created in order to eliminate corner and center effects.

3.2.3 Design

The experiment used a 2 (order: harvest images shown first vs. shape images shown first) x 2 (context: harvests vs. shapes) x 2 (gender: female vs. male) x 3 (edge number: low, medium, high) x 2 (angularity: angular vs. curved) x 2 (edge angle: acute vs. obtuse) x 2 (intrusion: with vs. without) design. Context, edge number, angularity, edge angle, and intrusion were within-subjects variables. Order and gender were between-subjects variables. Study area (non-environment focus vs. environment focus) was originally included in the design but was not significant and so was removed.

3.2.4 Hypotheses

Seven variables were explored in this study: context, order, gender, edge number, angularity, edge angle, and intrusion. With respect to context, we predicted that preference will change depending on the context the shape was presented in (harvests vs. shape). Both gender and order should demonstrate no significance with respects to preference ratings. In terms of complexity, we expected higher preference ratings for shapes with medium levels of complexity. We also believed the effect of angularity will be significant, with subjects preferring designs with curved features over their angular counterparts. In regards to edge angle, we predicted that designs with obtuse angles will be preferred. We also predicted that designs without intrusions will be preferred.

3.2.5 Participants

Eighty University of British Columbia students, 40 female and 40 male, with ages ranging from 20 to 45 years old (Female: $\bar{x}$= 23.82, SD = 3.27; Male: $\bar{x}$= 24.08, SD = 4.16), participated for monetary compensation. All had normal or corrected-to-normal vision. Informed written consent was obtained from each participant prior to the experiment.

3.2.6 Procedure

Each subject participated individually and was randomly assigned to an order condition; either to view image set 1 (shape) first or image set 2 first (harvest). Twelve sample images were shown prior to the actual image set to provide the subjects with the range of designs they will encounter to anchor their use of the rating scale and to avoid scale compression issues, as well as to familiarize them with the experiment interface. Images were presented sequentially in a different random order for each subject with no time limit for response, and subjects were required to rate each image for preference on a 1-10 scale (1=least preferred, 10=most preferred). After the rating of the first image set, they were asked to complete the poster ranking task; participants were asked to select and rank their top three most preferred designs and their bottom three least preferred designs. Subjects then took a short break to lessen fatigue. After the break, subjects were required to complete the rating of the second image set; followed by the poster ranking task. After the ratings of the two image sets, subjects were required to complete a follow-up demographic information questionnaire.

3.2.7 Analysis – Computer Ratings

Preference ratings were analyzed using a repeated measures analysis of variance (ANOVA). In the statistical analysis, the assumption of sphericity was not satisfied; therefore, the null hypothesis that the error covariance matrix is proportional to an identity matrix was rejected. As a result, the 'Greenhouse-Geisser' correction was used. A post hoc (Tukey's HSD) test was conducted to investigate where differences are significant in the interaction effect.

3.2.8 Analysis – Poster Rankings

Two methods were used to determine the three most preferred and three least preferred designs.

Method 1 - Within each image set, all 96 designs were counted and calculated. Each design was counted and calculated for two categories (most preferred 1 and least preferred 1). A value of +1 was assigned to every count in the most preferred category (ranked as 1) and a value of -1 was assigned to every count in the least preferred category (ranked as 1). These values (assigned to their respective categories) were then multiplied by their number of counts. Lastly, the sum of both categories was calculated.

Method 2 – Within each image set, all 96 designs were counted and calculated. Each design was counted and calculated for two categories: most preferred (1-3) and least preferred (-1-3). A value of +1 was assigned to every count in the most preferred category and a value of -1 was assigned to every count in the least preferred category. These values (assigned to their respective categories) were then multiplied by their number of counts. Lastly, the sum of both categories was calculated.

3.3 Results

3.3.1 Computer Ratings

The analysis revealed nineteen statistically significant characteristics relating to shape perception that affected individual preference (Table 2).

Table 2 ANOVA repeated measure results of shape attributes on preference ratings

Variable	df	Mean square	*F* ratio	*p*	Eta^2
Context	1	25.350	4.296	0.039*	0.013
Gender	1	273.600	13.289	0.000*	0.040
Order	1	162.526	7.894	0.005*	0.024
Angularity	1	14233.450	382.775	0.000*	0.548
Intrusion	1	1414.990	57.359	0.000*	0.154
Edge angle	1	889.350	48.386	0.000*	0.133
Edge number	1.397	181.398	14.089	0.000*	0.043
Context × edge angle	1	390.788	59.336	0.000*	0.158
Context × intrusion	1	41.667	4.445	0.036*	0.014
Context × edge number	1.769	13.960	3.378	0.035*	0.011
Gender × order	1	117.600	7.894	0.005*	0.024
Gender × angularity	1	418.044	11.242	0.001*	0.034
Gender × intrusion	1	256.784	10.409	0.001*	0.032
Order × angularity	1	366.301	9.851	0.002*	0.030
Angularity × intrusion	1	142.219	31.462	0.000*	0.091
Angularity × edge angle	1	129.067	25.156	0.000*	0.074
Angularity × edge number	1.941	27.985	9.235	0.000*	0.028
Edge number × edge angle	1.899	11.917	3.357	0.038*	0.011
Edge number × edge angle × angularity	1.986	18.937	7.516	0.001*	0.023

* Statistically significant results at the p = 0.05 level.

Context reached significance as a main effect, $F (1, 316) = 4.296$, $p < .039$, $Eta^2 = .013$ (Figure 11), demonstrating a small effect on participants' preference for the two image sets. Mean ratings for the harvest image set was higher than the shape image set (less than 2%).

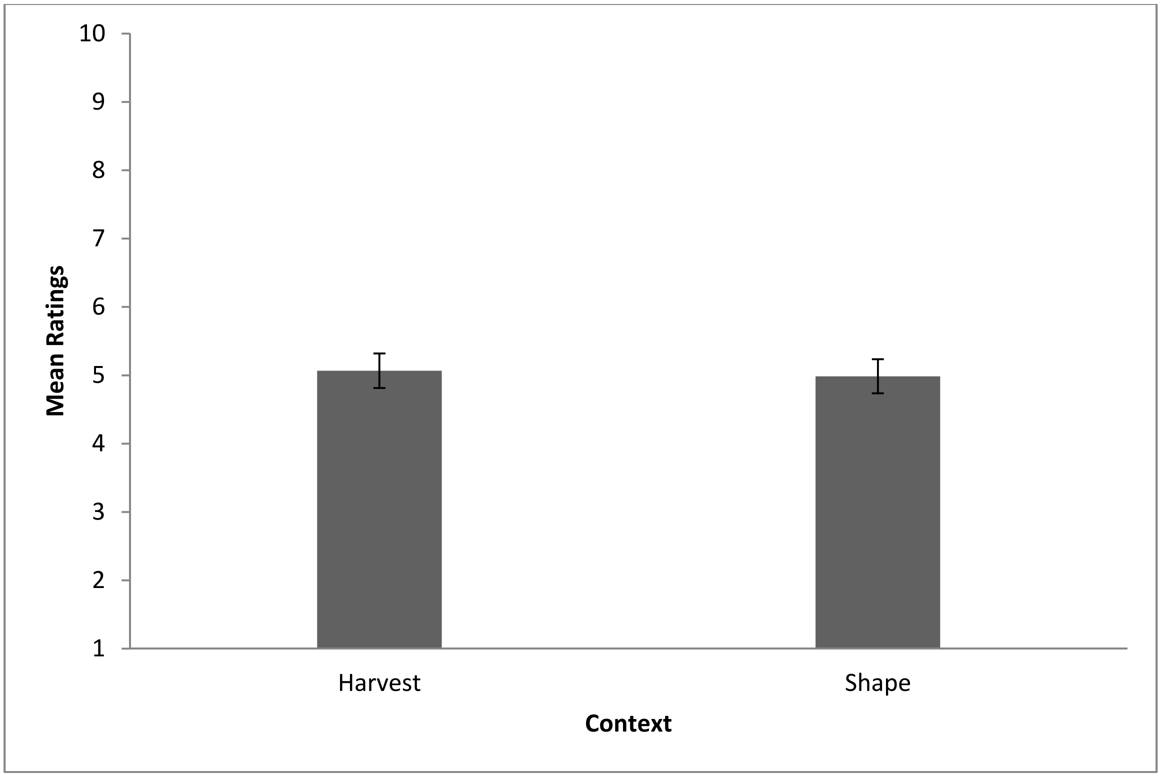


Figure 11 Relationship of mean ratings with context

Gender, as a main effect, also reached significance: $F\ (1, 6505.871) = 13.289$, $p < .000$, $Eta^2 = .040$ (Figure 12), such that overall mean ratings of male participants were higher than those from female participants (by 5%).

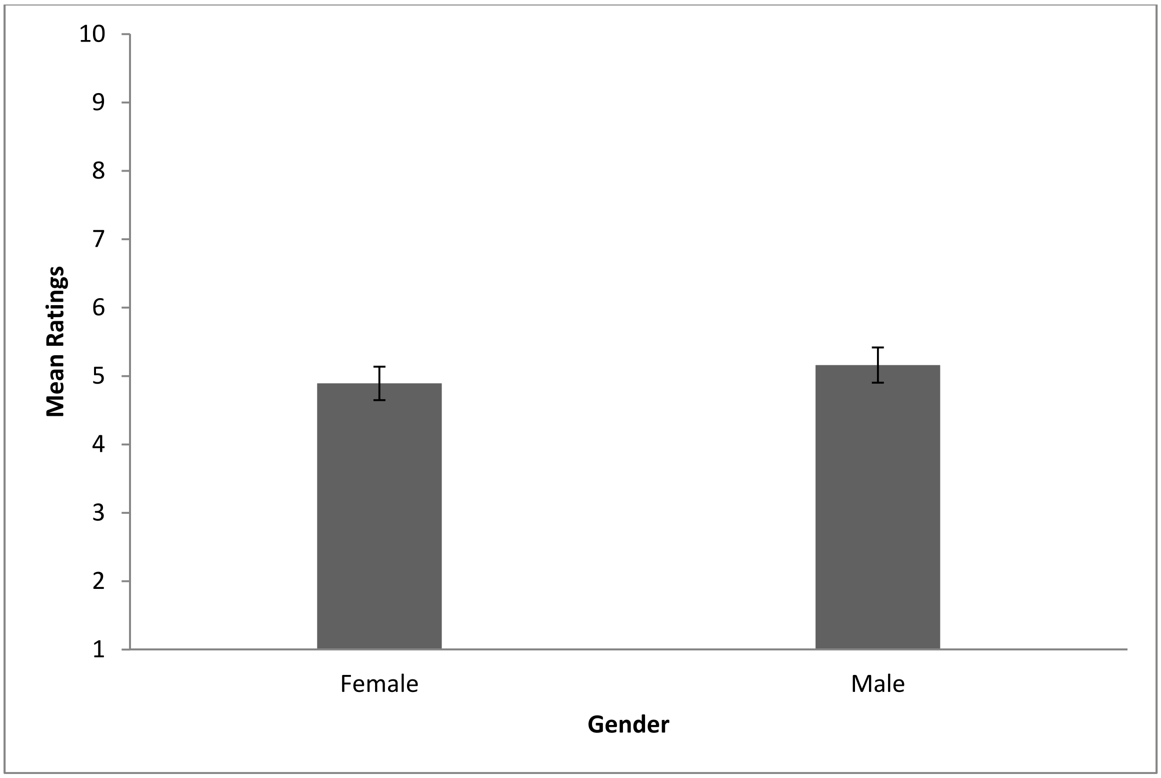


Figure 12 Relationship of mean ratings with gender

There was also a main effect of order, F (1, 6505.871) = 7.894, $p < .005$, $Eta^2 = .024$ (Figure 13). Participants who saw the shape image set first demonstrated higher mean ratings than participants who saw the harvest image set first; however, only by 4%.

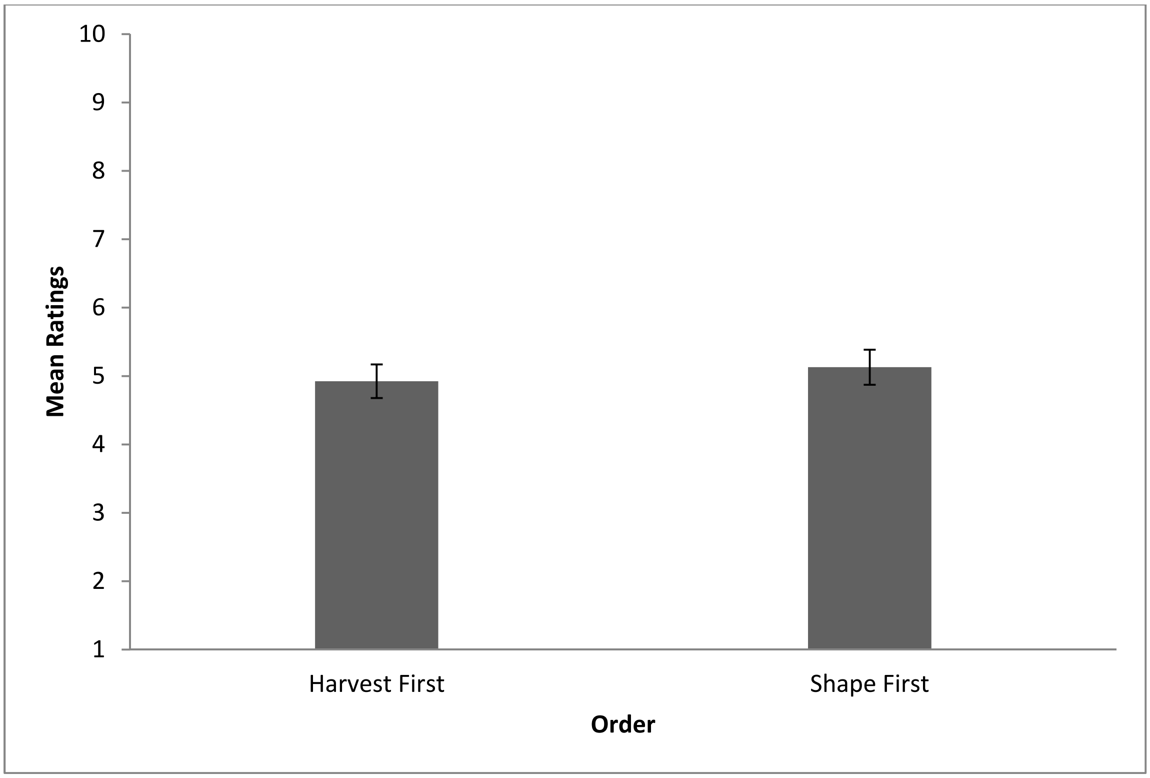


Figure 13 Relationship of mean ratings with order

The largest main effect related to shape was angularity, $F (1, 316) = 382.775$, $p < .000$, $Eta^2 = .548$ (Figure 14). Generally, the preference for curved shapes was higher than their angular counterparts by 38%.

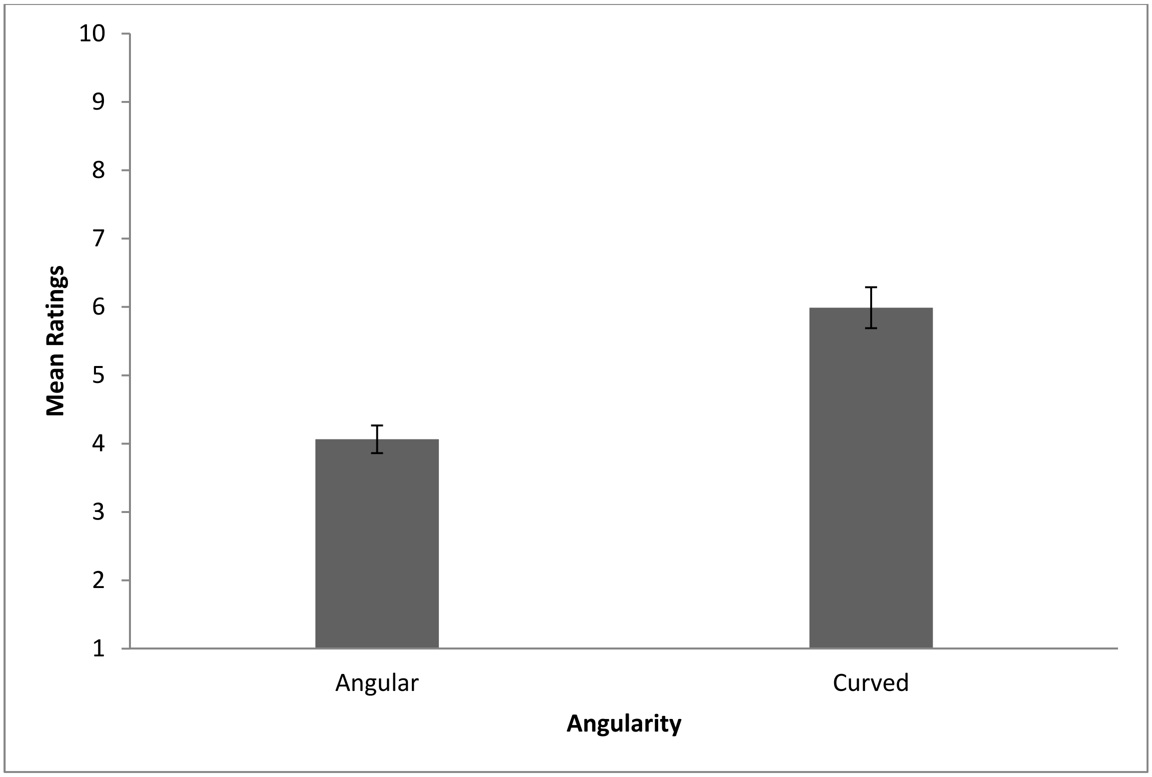


Figure 14 Relationship of mean ratings with angularity

When considering effects of shape manipulations on individual preference, there was a main effect of intrusion, F (1, 316) = 57.359, $p < .000$, $Eta^2 = .154$ (Figure 15), such that participants preferred shapes without intrusion than those shapes with intrusion (by 12%).

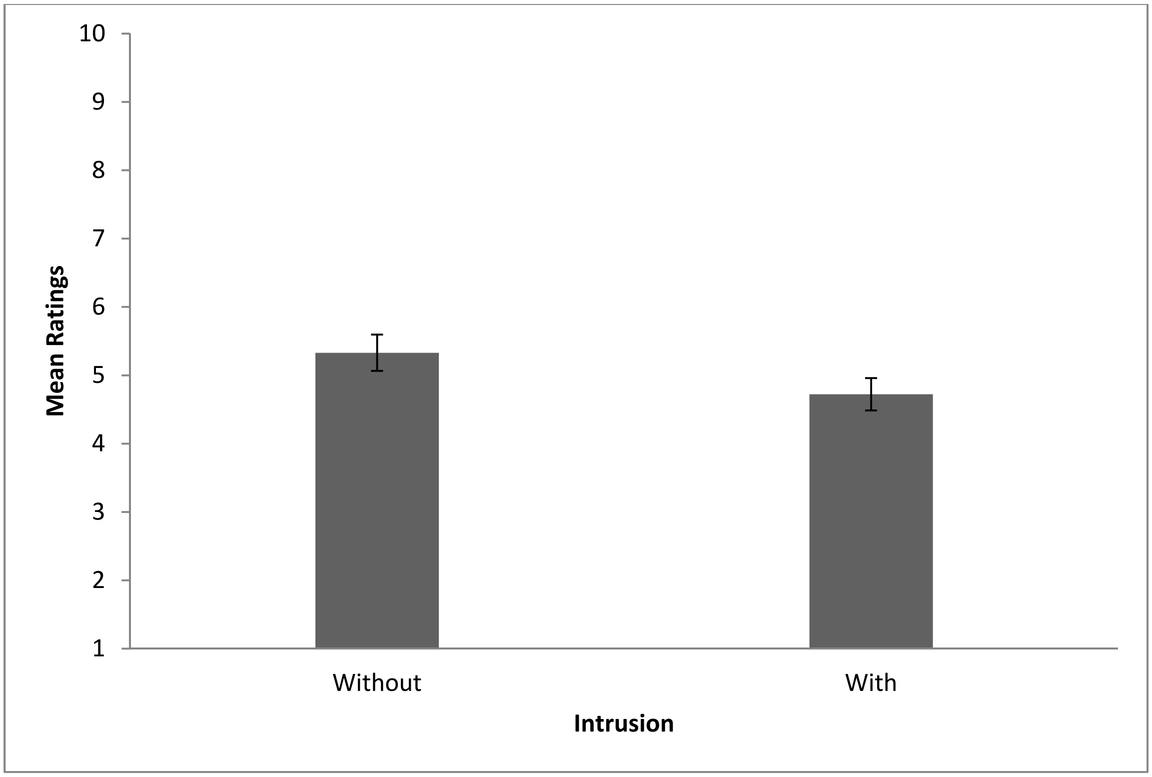


Figure 15 Relationship of mean ratings with intrusion

There was also a main effect of edge angle, $F(1, 316) = 48.386$, $p < .000$, $Eta^2 = .133$ (Figure 16), where shapes with obtuse angles were preferred over shapes with acute angles (by 10%).

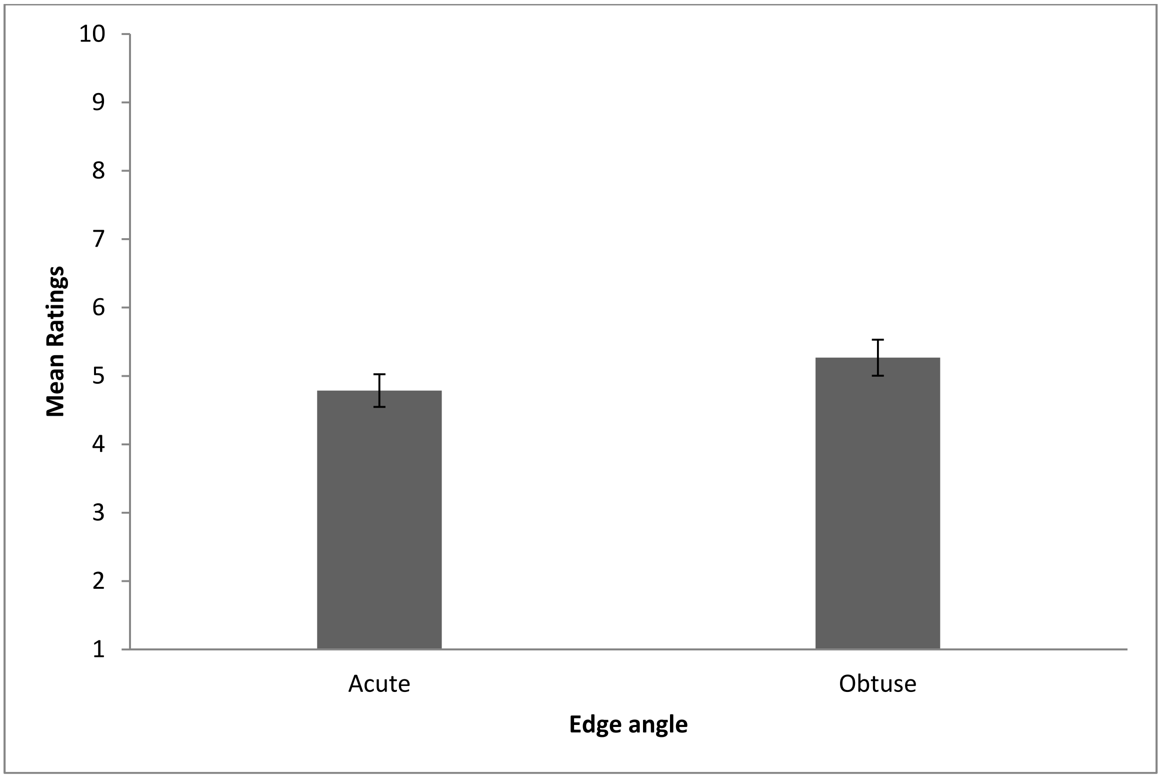


Figure 16 Relationship of mean ratings with edge angle

Edge number also demonstrated significance as a main effect, $F(1.397, 441.310) = 14.089$, $p < .000$, $Eta^2 = .043$ (Figure 17), such that participants preferred shapes with low edge number, followed by medium edge number, then shapes with high edge number. Mean ratings for shapes with low edge number and shapes with high edge number demonstrated a bigger difference (6%); the difference between preference for shapes with high edge number and medium edge number was less than 1%.

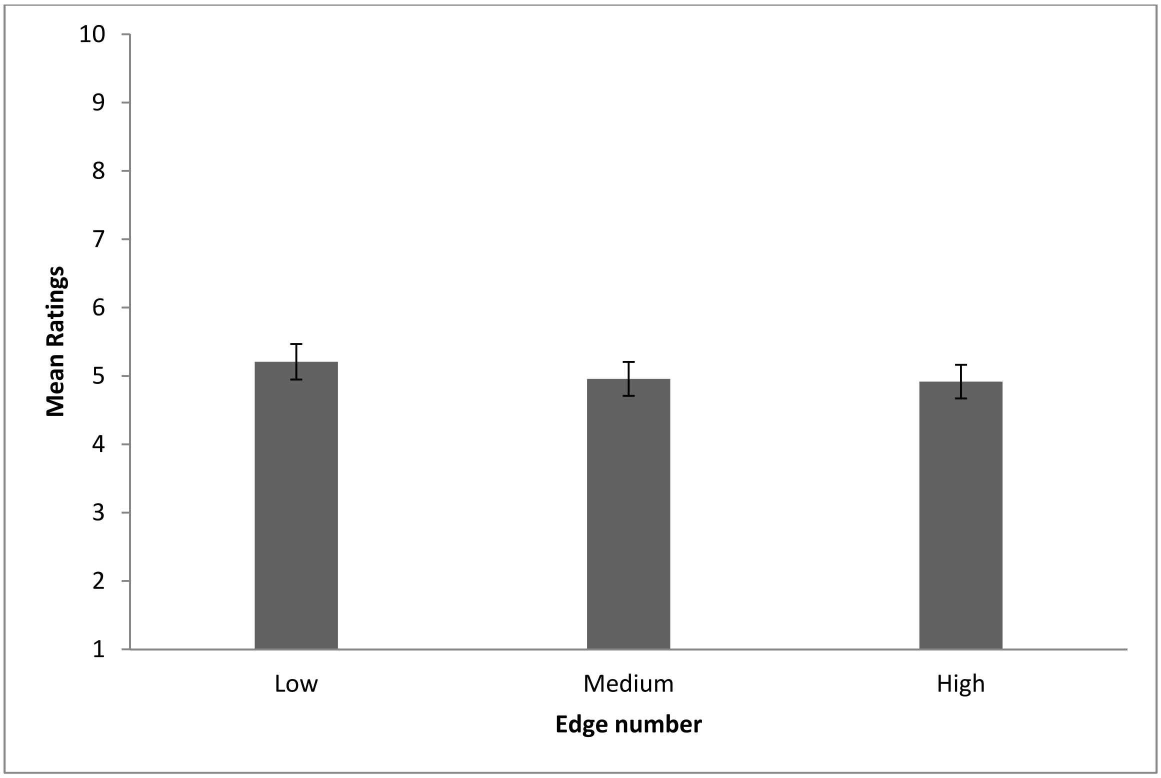


Figure 17 Relationship of mean ratings with edge number

The interaction effect of context and edge angle was significant, $F(1, 316) = 59.336$, $p < .000$, $Eta2 = .158$ (Figure 18). Tukey's HSD test has indicated all differences between the two variables to be significant. The difference in mean ratings (by 16%) between shapes with acute angles and shapes with obtuse angles was higher in the context of harvest designs. In contrast, the difference was sizably smaller in the context of shape, only by 4%. Shapes with acute angles were less preferred in the harvest context than in the shape context (by 5%); whereas shapes with obtuse angles were more preferred in the harvest context than in the shape context (by 8%).

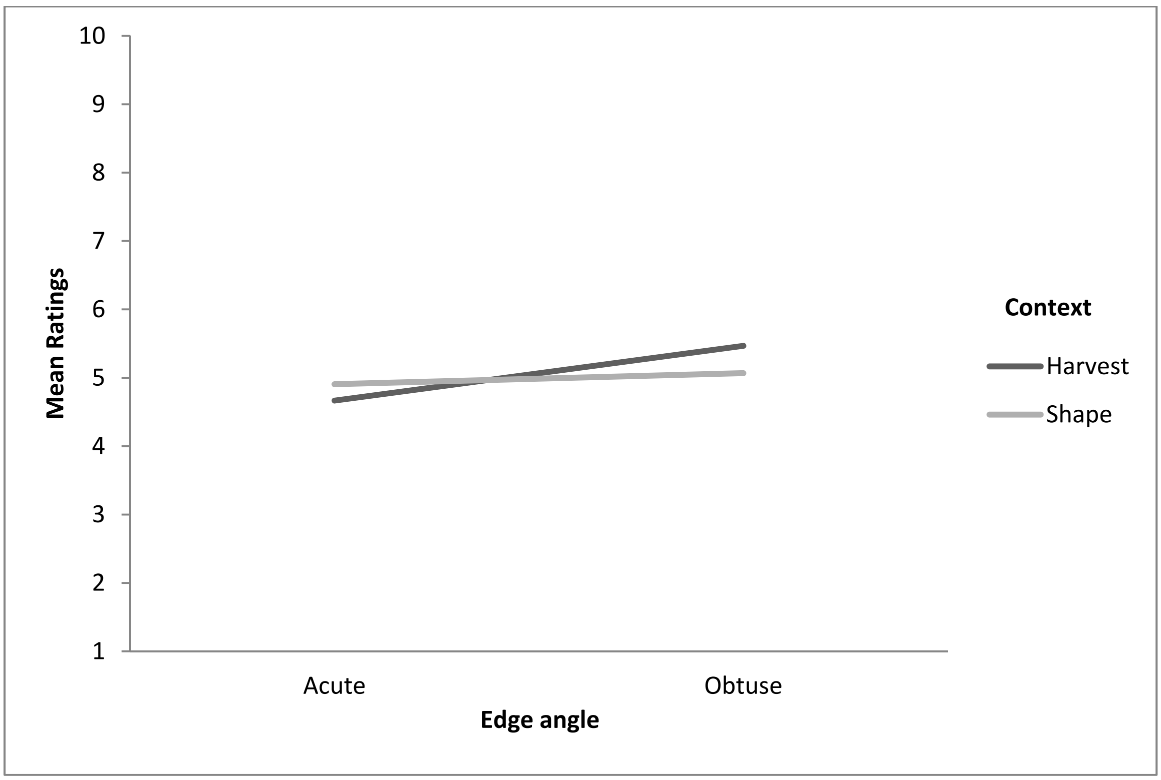


Figure 18 Interaction effect of context and edge angle: mean ratings of the two levels of edge angle for context (harvest vs. shape)

There was an interaction effect of context and intrusion, $F(1, 316) = 4.445$, $p < .036$, Eta2 = .014 (Figure 19). Tukey's HSD test revealed that under the with intrusion condition, context had no significant effect. However, the effect of context was significant under the without intrusion condition; in which harvest designs were rated higher in preference than their shape counterparts by 3%.

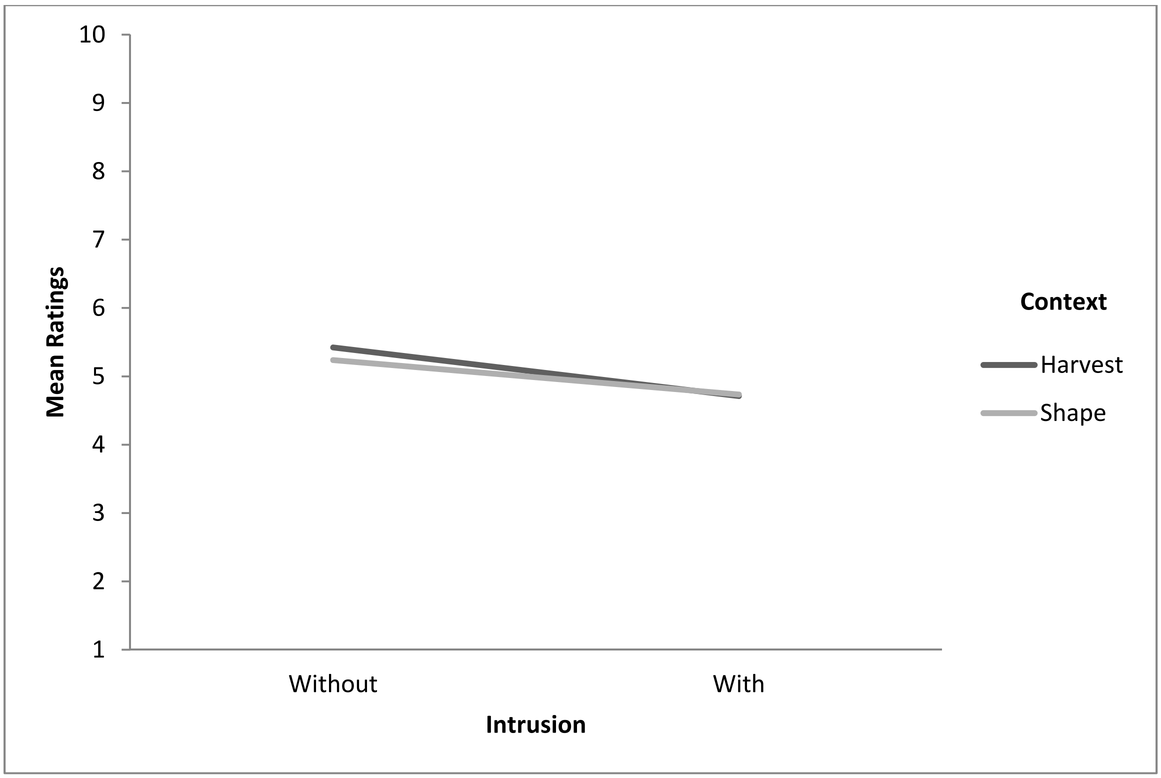


Figure 19 Interaction effect of context and intrusion: mean ratings of the two levels of intrusion for context (harvest vs. shape)

Another significant interaction was found between context and edge number, F (1.769, 558.912) = 3.378, p < 0.41, Eta2 = .011 (Figure 20). However, Tukey's HSD identified the only significant difference was between context and low edge number as harvest designs were rated higher in preference by 3% than the shape designs.

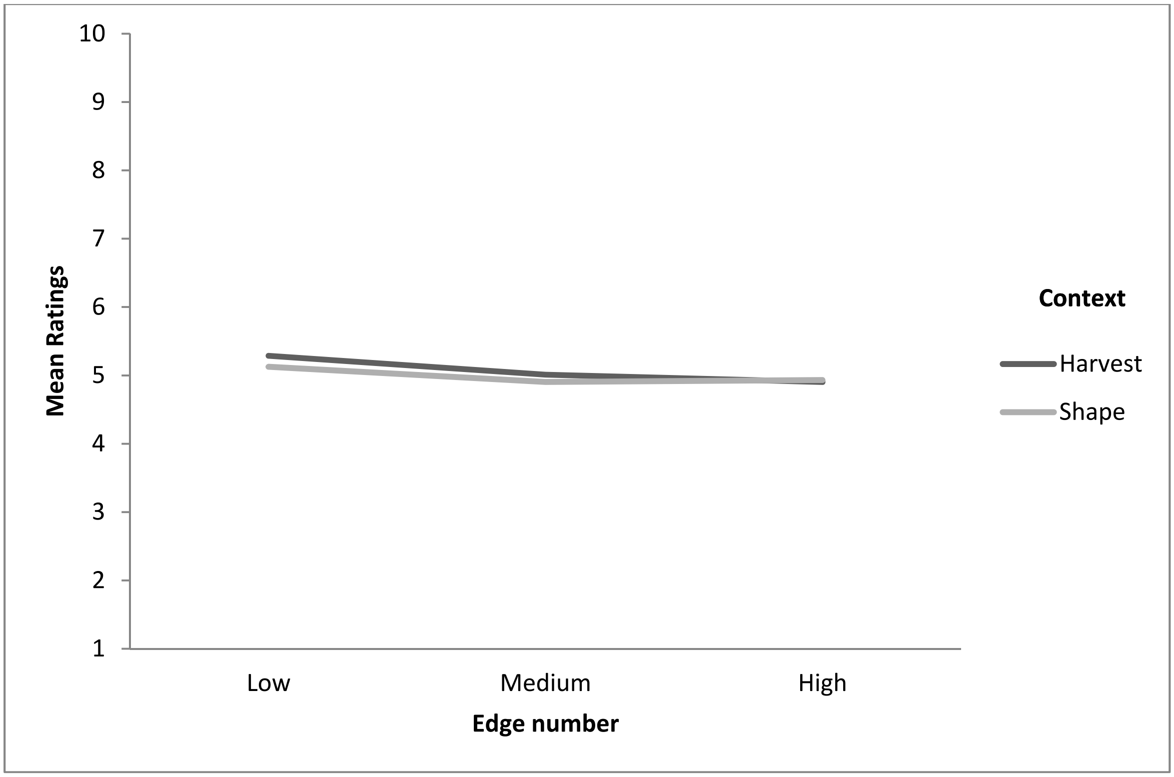


Figure 20 Interaction effect of context and edge number: mean ratings of the two levels of context for edge number (low, medium, high)

The interaction of gender and order was also statistically significant, F (1, 6505.871) = 7.894, $p < .005$, Eta2 = .024 (Figure 21). Tukey's HSD test revealed that gender had an effect under the shape first condition, where males generally produced higher preference ratings (by 9%). Moreover, the effect of order was only significant for males as preference ratings were higher (by 7%) when they saw the shape image set first.

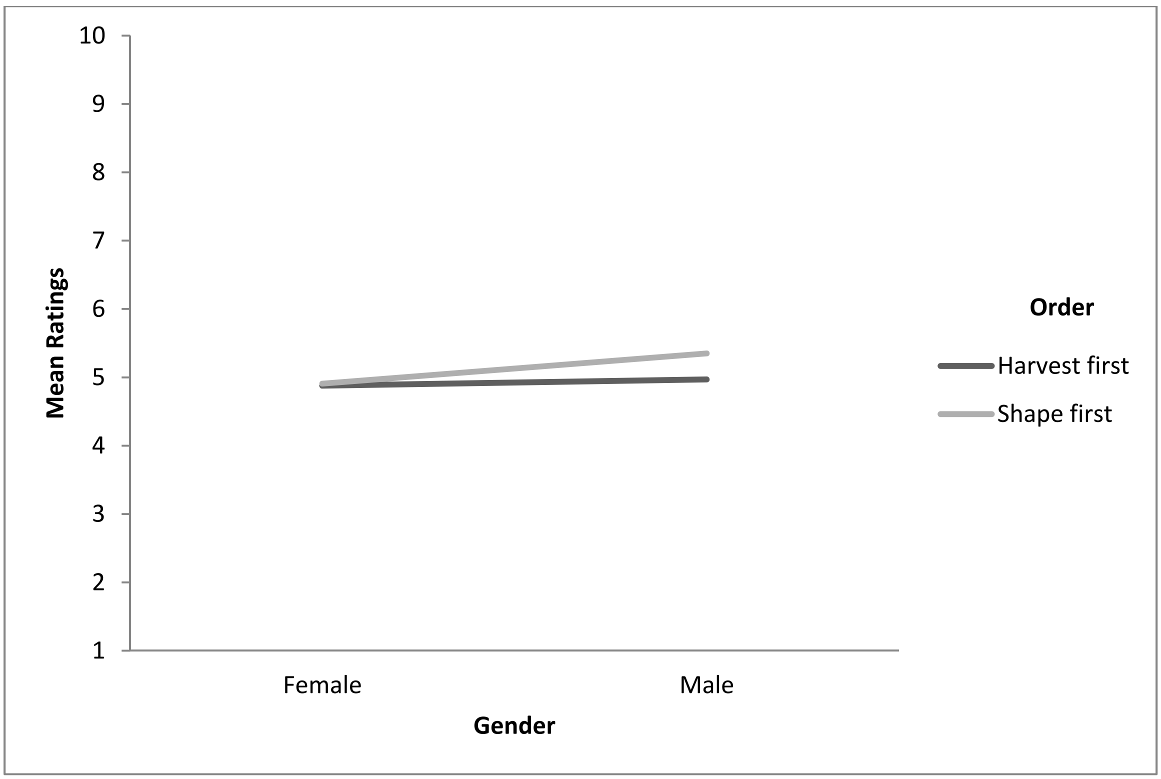


Figure 21 Interaction effect of gender and order: mean ratings of female and male participants for order (harvest first vs. shape first)

The interaction between gender and angularity was significant, $F(1, 316) = 11.242$, $p < .001$, Eta2 = .034 (Figure 22). Tukey's HSD showed that under the curved condition, gender demonstrated no significant effect. The difference in preference under the angular condition between females and males was significant; male participants generated higher preference ratings than those of female participants by 14%.

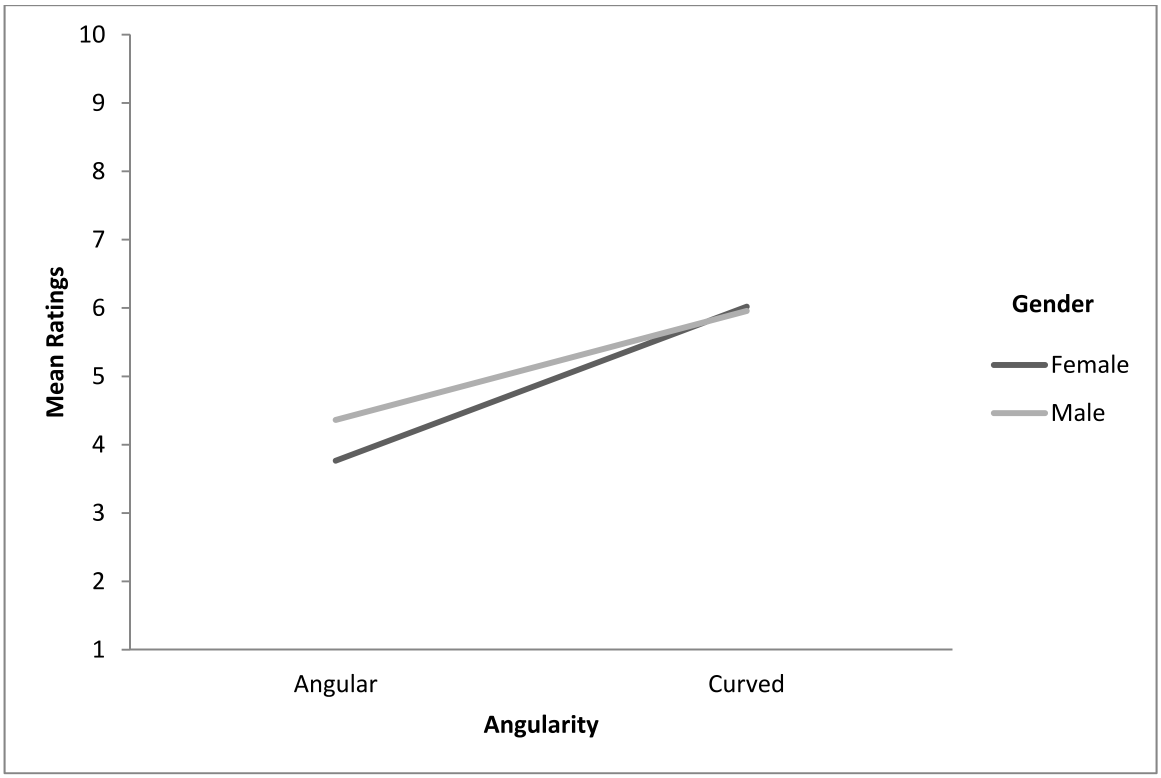


Figure 22 Interaction effect of gender and angularity: mean ratings of female and male participants for angularity (angular vs. curved)

There was also a significant interaction effect of gender and intrusion, $F (1, 316) = 10.409$, $p < .001$, $Eta2 = .032$ (Figure 23). Tukey's HSD test indicated that gender effect under the without intrusion condition to be insignificant. However, a significant gender effect was found for designs with intrusions; where males demonstrated higher preference than females (by 7%).

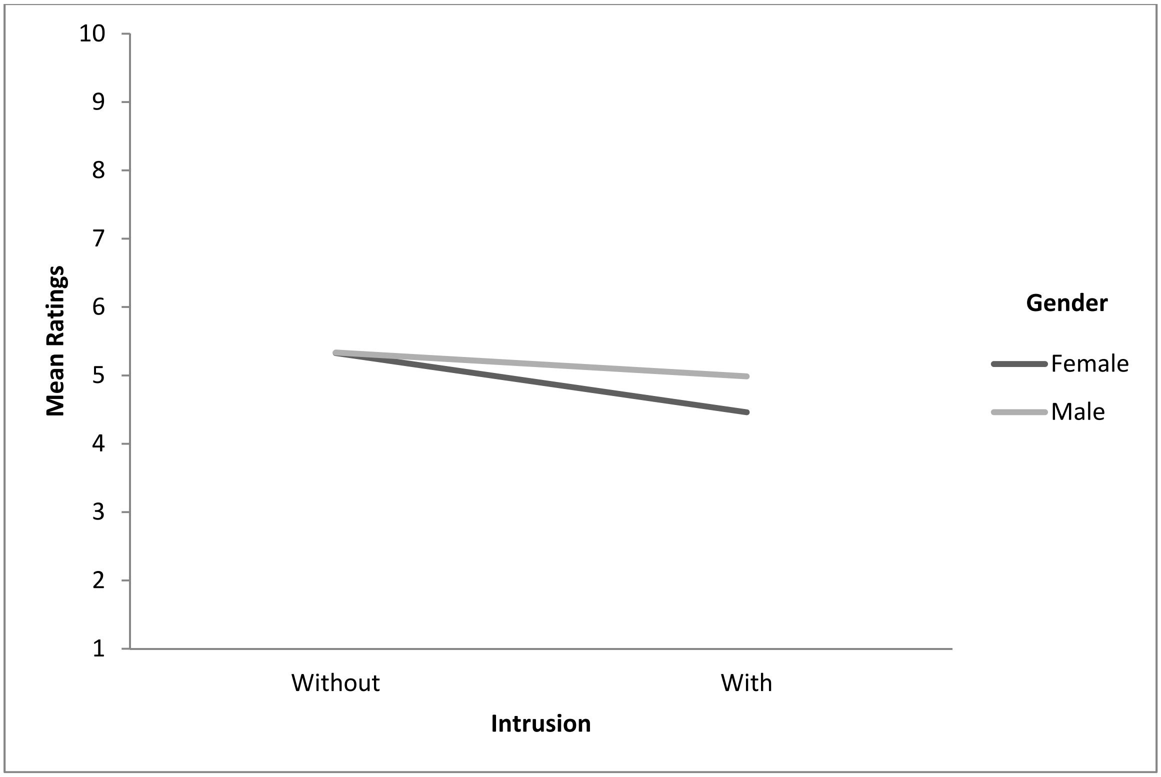


Figure 23 Interaction effect of gender and intrusion: mean ratings of female and male participants for intrusion (without vs. with)

The interaction between order and angularity demonstrated significance as well, $F(1, 316) = 9.851$, $p < .002$, Eta2 = .030 (Figure 24). Results from the Tukey's HSD test demonstrated no significance under the angular condition. Whereas under the curved condition, participants who saw the shape image set first produced higher preference ratings (by 9%) than those presented with the harvest image set first.

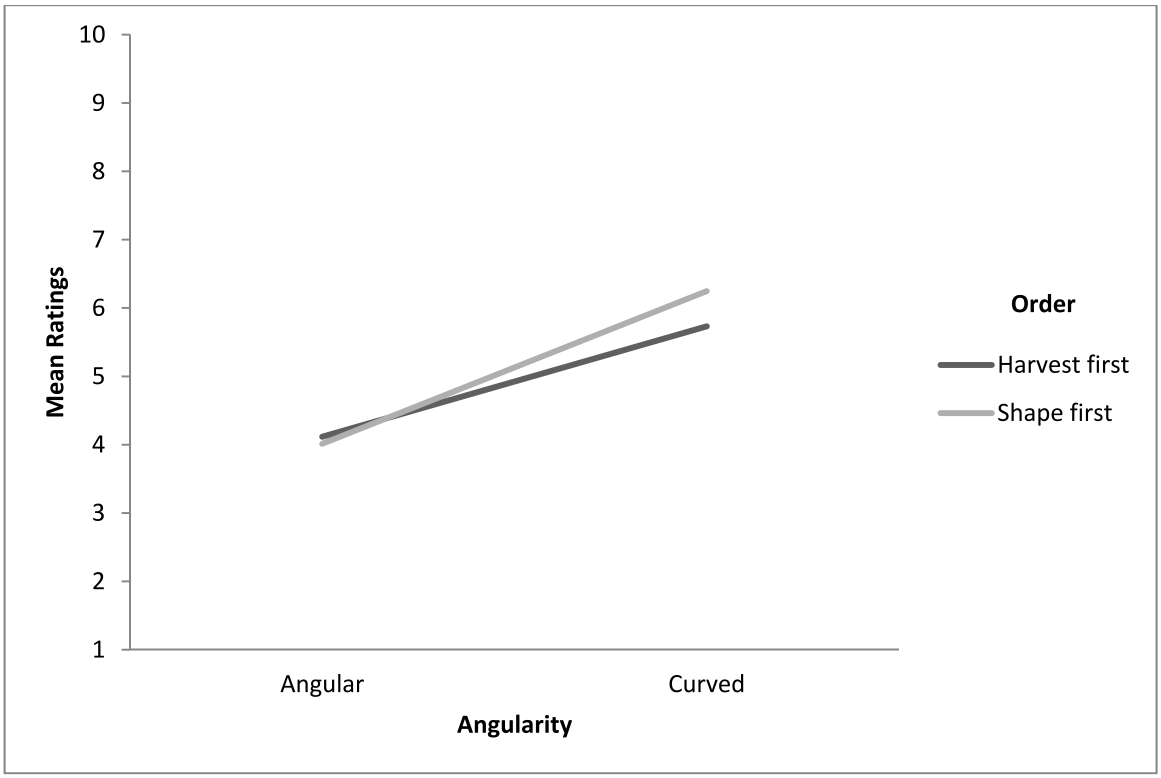


Figure 24 Interaction effect of order and angularity: mean ratings of the two levels of order for angularity (angular vs. curved)

There was also an interaction effect of angularity and intrusion, $F (1, 316) = 31.462$, $p < .000$, $Eta2 = .091$ (Figure 25). Tukey's HSD test indicated all differences between the two variables to be significant. Participants preferred curved shapes without intrusion more than angular shapes with intrusion, by a considerable amount (51%). The difference in ratings between the two levels of intrusion was smaller when the shapes were curved (7%); difference was bigger when the shapes were angular (20%).

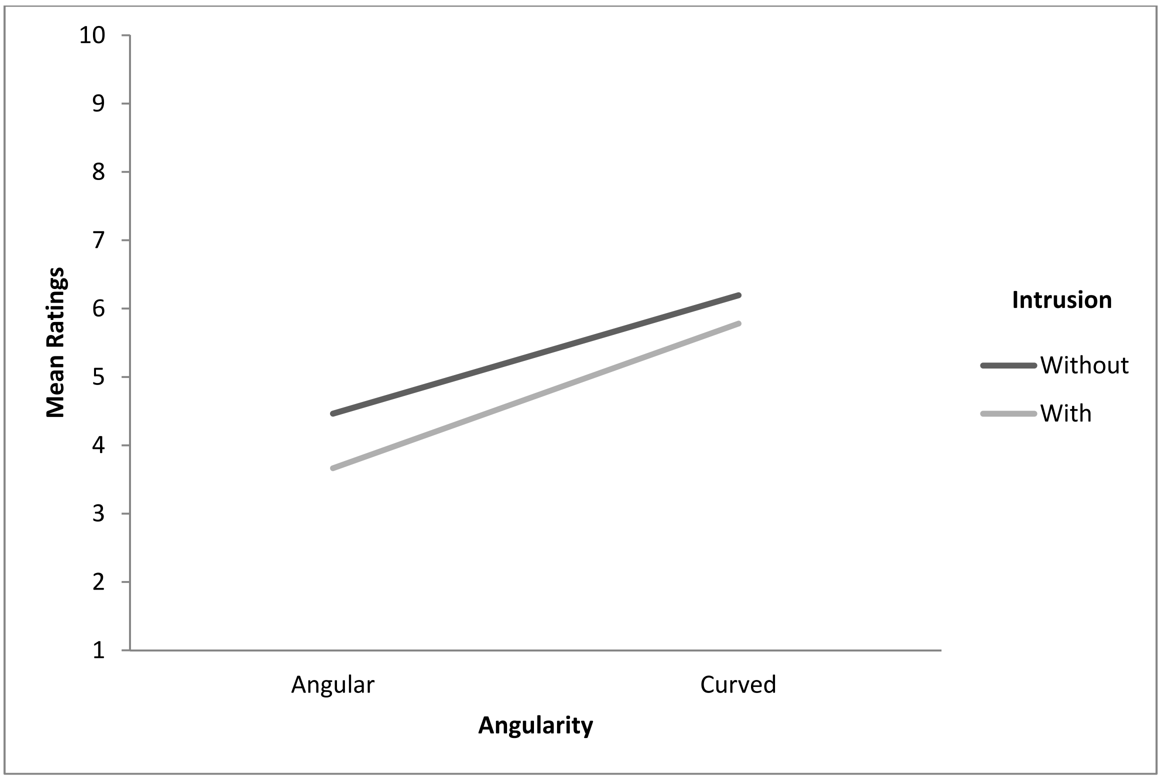


Figure 25 Interaction effect of angularity and intrusion: mean ratings of the two levels of intrusion for angularity (angular vs. curved)

There was also a significant interaction of angularity by edge angle, F (1, 316) = 25.156, p < .000, Eta2 = .074 (Figure 26), where curved shapes with obtuse angles were rated higher in preference (49%) than angular shapes with acute angles. Edge angle demonstrated a smaller effect when shapes were curved (5% difference between the two levels); the difference in ratings was higher when shapes were angular (16%). Tukey's HSD test indicated all differences between the two variables to be significant.

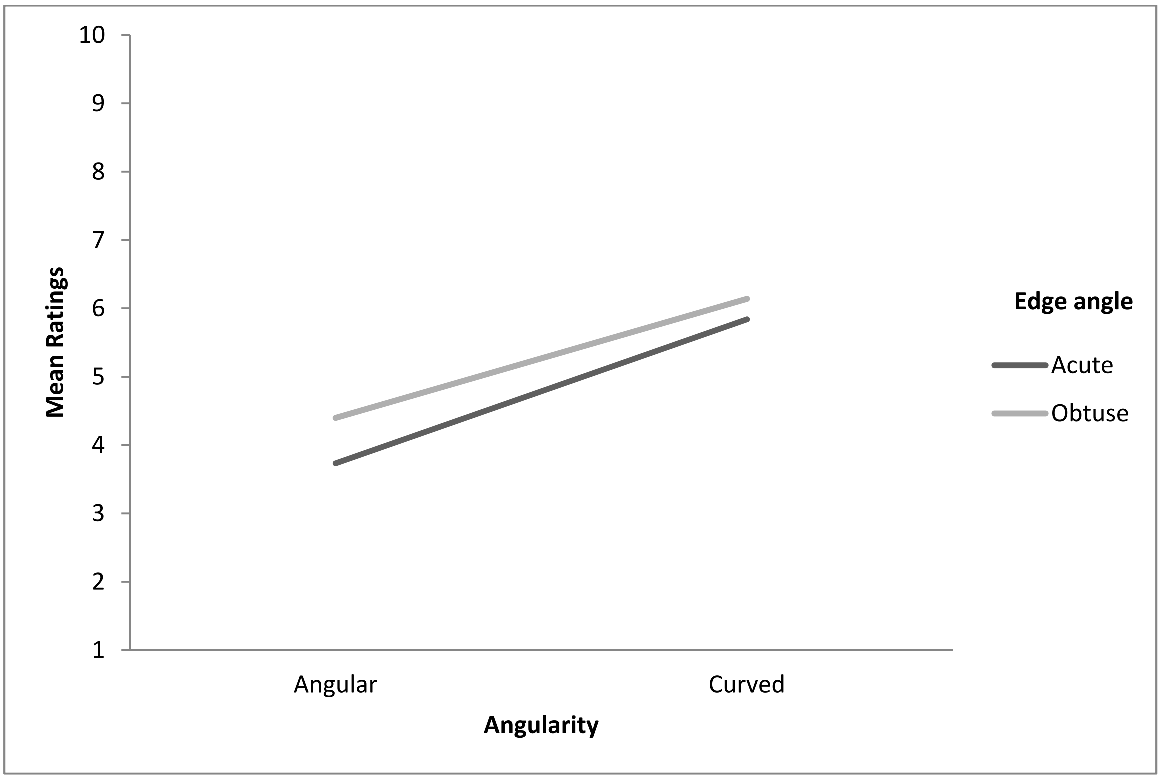


Figure 26 Interaction effect of angularity and edge angle: mean ratings of the two levels of edge angle for angularity (angular vs. curved)

The interaction between angularity and edge number was also found to be significant, F (1.941, 613.379) = 9.235, $p < .000$, Eta2 = .028 (Figure 27). However, Tukey's HSD test revealed the effect of angularity was significant under all three levels of edge number (low: 34%, mid: 41%, high: 41%). However, edge number had no significant effect under the curved condition. The difference between medium and high edge number under the angular condition was also insignificant. However, the differences between low and medium as well as low and high demonstrated significance; with higher ratings generated by low edge number, by 9% in both cases.

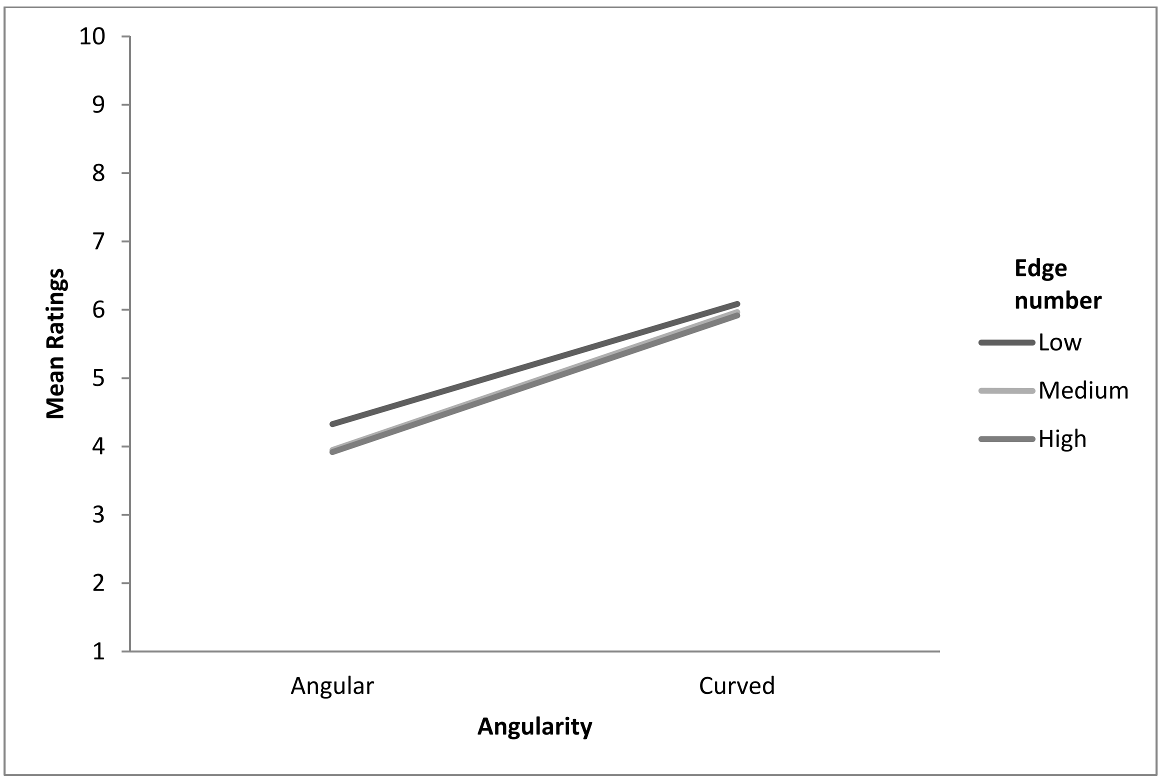


Figure 27 Interaction effect of angularity and edge number: mean ratings of the two levels of angularity for edge number (low, medium, high)

There was also a significant interaction of edge number by edge angle, F (1.899, 600.036) = 3.357, $p < .038$, Eta2 = .011 (Figure 28). Tukey's HSD test indicated a significant edge angle effect at all three levels of edge number (low: 8%, medium: 9%, high: 12%). Under the obtuse condition, only the difference between low edge number and medium edge number (4%) was significant. Under the acute condition, the difference between low edge number and medium edge number demonstrated significance, at 5%. Furthermore, the difference between low edge number and high edge number (8%) also reached significance.

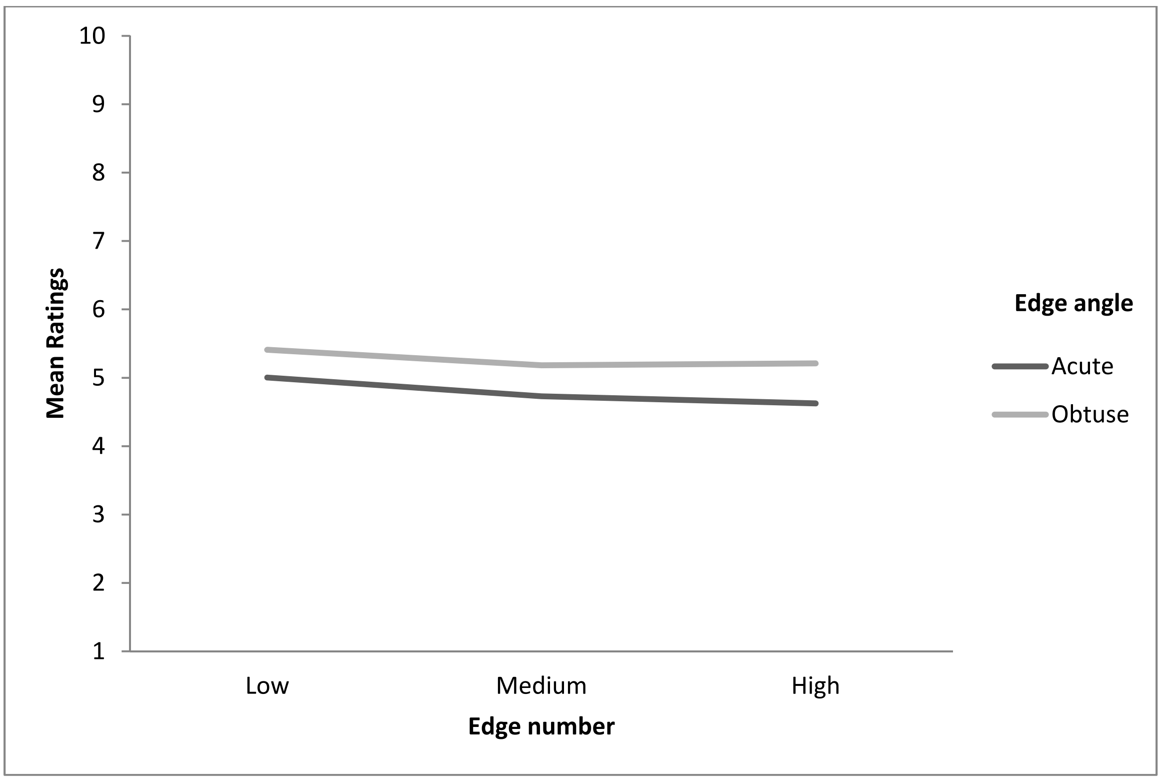


Figure 28 Interaction effect of edge number and edge angle: mean ratings of the two levels of edge angle for edge number (low, medium, high)

A three-way interaction effect between angularity, edge number, and edge angle also reached significance, F (1.986, 627.729) = 7.576, $p < .001$, Eta2 = .023 (Figure 29). Tukey's HSD test indicated that under the angular condition, edge angle demonstrated significant effects at each level of edge number (low: 10%, medium: 18%, high: 21%). In terms of edge number with respect to acute angle, only the differences between low and medium as well as low and high were significant, respectively at 12% and 15%. Moreover, edge number demonstrated no significant effect when it comes to designs with obtuse angles. Under the curved condition, the effect of edge angle was able to demonstrate significance for both low and high edge numbers, with differences in preference ratings both at 6%. In terms of edge number in relation to edge angle, all three levels of edge number demonstrated no significant effect under both acute and obtuse conditions.

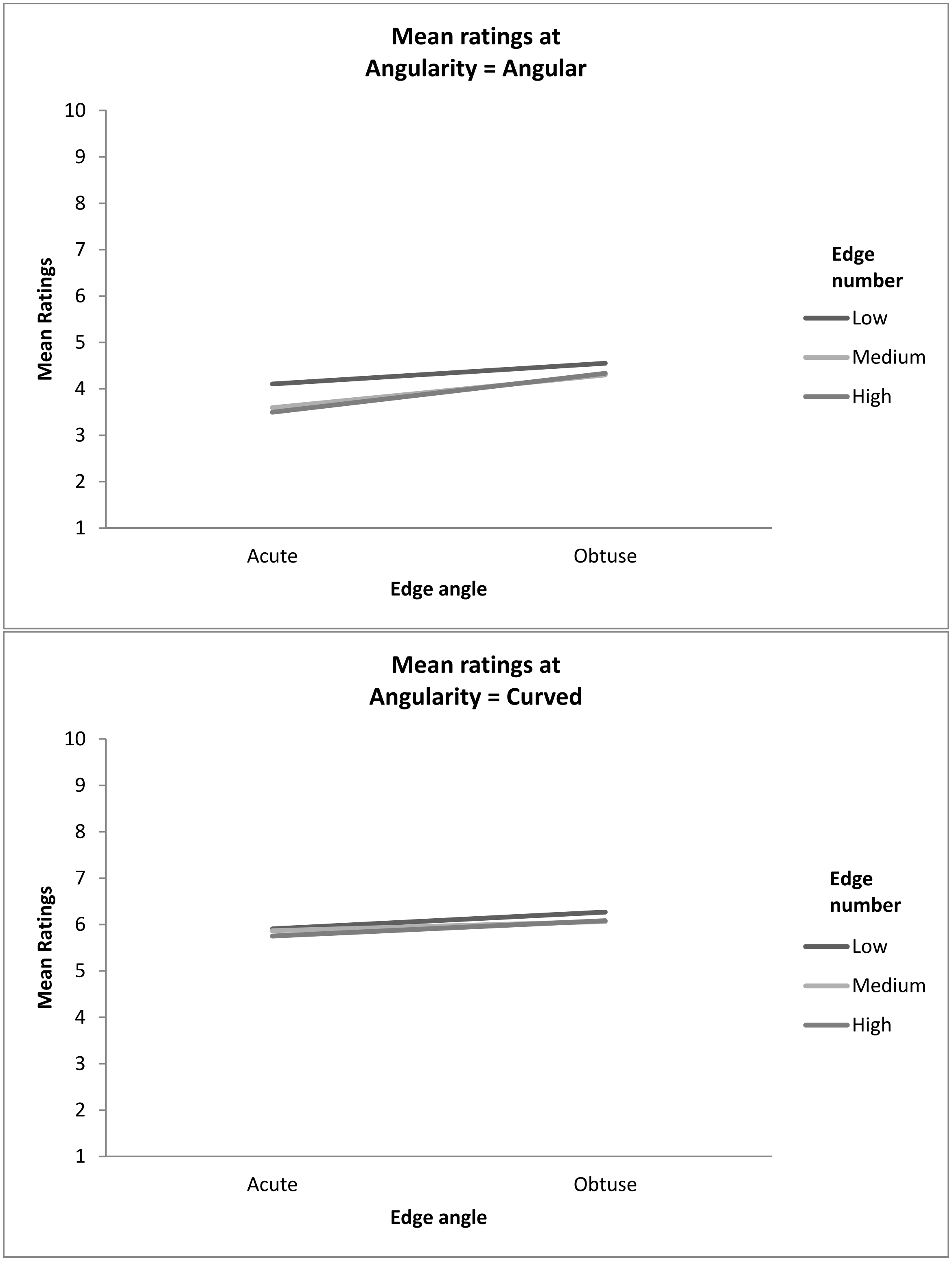


Figure 29 Three-way interaction effect of edge number, and edge angle, and angularity: mean ratings of the two levels of edge angle for edge number (low, medium, high), under two angularity conditions (angular vs. curved)

3.3.2 Poster Rankings

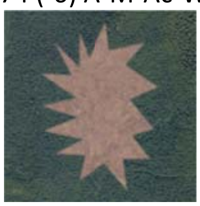
The poster analysis revealed the rankings for the three most preferred designs and the three least preferred designs (Table 2). Design number, ranking value, and shape features are indicated under each design. Shape features included angularity (A=angular, C=curved), edge number (L=low, M=medium, H=high), edge angle (Ac=acute, O=obtuse), and intrusion (WO=without, WI=with).

Table 3 Poster analysis results of the rankings of the three most preferred designs and the three least preferred designs. Design number, ranking value, and shape features are indicated under each design. Shape features included angularity (A=angular, C=curved)

Ranking	Method 1 - Harvest	Method 2 - Harvest	Method 1 - Shape	Method 2 - Shape
Most preferred 1	 #42 (+9) C-H-O-WI	 #86 (+16) C-L-O-WO	 #5 (+7) C-H-Ac-WI  #9 (+7) C-L-O-WO	 #86 (+10) C-L-O-WO
Most preferred 2	 #9 (+7) C-L-O-WO	 #9 (+11) C-L-O-WO  #42 (+11) C-H-O-WI	 #86 (+3) C-L-O-WO  #67 (+3) C-M-O-WO	 #9 (+9) C-L-O-WO

			 #60 (+3) C-L-Ac-WI  #96 (+3) A-L-O-WI	
Most preferred 3	 #86 (+5) C-L-O-WO  #81 (+5) A-L-O-WO	 #73 (+10) C-H-O-WI	 #30 (+2) C-L-O-WO  #6 (+2) C-L-O-WI  #59 (+2) C-L-Ac-WI  #70 (+2) C-H-O-WI  #80 (+2) C-M-O-WI	 #67 (+8) C-M-O-WO

			 #25 (+2) C-M-O-WI  #73 (+2) C-H-O-WI  #12 (+2) C-M-Ac-WI  #57 (+2) C-H-Ac-WI  #68 (+2) A-M-O-WO	
Least preferred 1	 #11 (-20) A-H-Ac-WI	 #11 (-32) A-H-Ac-WI	 #11 (-10) A-H-Ac-WI  #74 (-10) A-M-Ac-WI	 #74 (-21) A-M-Ac-WI

Least preferred 2	 #54 (-9) A-H-Ac-WI	 #54 (-25) A-H-Ac-WI	 #54 (-6) A-H-Ac-WI	 #11 (-20) A-H-Ac-WI
Least preferred 3	 #74 (-6) A-M-Ac-WI  #66 (-6) A-H-Ac-WO	 #74 (-19) A-M-Ac-WI	 #62 (-5) A-H-Ac-WI  #46 (-5) A-M-Ac-WI	 #54 (-18) A-H-Ac-WI

3.3.3 Expansion to Include Aerial View in VRM

66 out of 80 (83%) participants selected yes to the question "Our question is whether or not you feel that it would make sense to expand our visual management of the forest to include this new aerial view".

3.4 Discussions and Conclusions

3.4.1 Computer Ratings

In this experiment, the effects that different characteristics of shape have on preference ratings were investigated in the framework of different context conditions (harvests vs. shapes). Manipulations of order, context, edge number, angularity, edge angle, and intrusion were tested. When considering preference for aesthetics, there were main effects of context, gender, order, angularity, intrusion, edge angle, and edge number. A total of twelve interactions between these variables were significant. Since interaction effects represent the combined effects of factors on the dependent variable, the impact of one factor depends on the level of the other factor. Results and interpretations of one variable's effect must be qualified in terms of the impact of the second variable. Thus, we devote to interpret our findings based on the interaction effects.

The largest interaction effect was between context and edge angle. Results indicate that edge angle had a stronger effect on preference ratings in the harvest condition than in the shape condition. Harvest block designs with acute angles were rated lower in preference as they may appear to be less natural and perceived as unfitting to the existing landscape. This preference can be explained using the concept of naturalness, as existing literature clearly states that people prefer organic and undulated looking shapes especially in a natural setting (Bell, 2001; Chamberlain & Meitner, 2012; Gobster, 1999; Kaplan & Kaplan, 1989; A. Ode et al., 2009; Purcell & Lamb, 1998; Tveit et al., 2006; Ulrich, 1979). The same pattern was observed in the interaction of context and intrusion. Results demonstrated that preference ratings for designs without intrusion were higher in the harvest condition. We suspect that designs without intrusions are seen as more conventional and may be perceived as less threatening, especially in the natural setting. In terms of the interaction of context and edge number, the effect of context was only significant under the low edge number condition. In which harvest designs were rated higher in preference than their shape counterparts. Generally speaking, there seems to be a preference tendency towards designs low in edge number. This phenomenon is more pronounced with the inclusion of context. This might be due to the levels of edge numbers used in the stimuli sets (low: 8, medium: 16, high: 24), in which 24 edge count appears to be too visually complex and unnatural, particularly in the design of harvest blocks.

An interaction of gender and order was observed in this experiment. Both genders generated higher preference ratings when presented with the shape image set first. Female participants who saw the shape image set first rated all designs higher in preference, but less than 1%. This trend was more prominent for male participants. When presented with the shape image set first, overall mean ratings by male participants were higher than females; male participants who saw the harvest image set first also rated all designs higher than females. The reasoning behind such trend is unclear. While these effects are small, they may warrant further investigation. Results also indicate an interaction of angularity and gender; with angularity having a bigger effect on female participants than male participants. Mean ratings by female participants increased by 46% from angular to curved, male participants rated the curved designs higher than their angular counterparts by 31%. The effect of gender was significant under the angular condition with male participants generating higher preference ratings than female participants. However, gender demonstrated insignificance under the curved conditions. In other words, there is a stronger consensus for curved designs in terms of preference. The interaction of gender and intrusion also demonstrate similar effects. The effect of intrusion was more pronounced in preference ratings provided by female participants; with female participants' ratings increased by 18% from designs with intrusion to designs without intrusion, and mean ratings of male participants having an increase of 7%. The effect of gender was insignificant under the condition of without intrusion, again demonstrating consensus between females and males in preference ratings. These findings suggest that the predictability of preference with respect to order, angularity, and intrusion effects is higher for female participants. Although we are uncertain about the reasoning behind such effects; these findings certainly provide implications for future research to explore possible explanations for such effects.

Another interesting discovery was the interaction of angularity and order. The effect of order demonstrated significance under the curved condition, in which participants who saw the shape image set first produced higher ratings. Order had no effect on preference ratings when it comes to angular designs. A possible explanation is that the edges of the designs are less visually protruding in the context of harvest than those in the shape condition. Therefore, when presented with shape image set first, the distinction between the angular and curved designs might be more prominent resulting in higher preference ratings for all curved designs. Moreover, other shape attributes tested might also be accountable in explaining this trend.

Overall, curved designs were rated higher in preference than their angular counterparts by 40%. This finding is consistent with existing research, where humans demonstrate a strong tendency preferring lines, shapes, and objects with curved features (Bar & Neta, 2006, 2007; Larson et al., 2008, 2007; Silvia & Barona, 2009; Westerman et al., 2012). Such preference is argued to be an evolutionary advantage as angular forms suggest threat and danger (Darwin, 1872). Angularity demonstrated the strongest effect compared to other shape characteristics pertaining to preference ratings. The interaction of angularity and intrusion also reached significance. Curved designs without intrusions were most preferred. We can also see that participants generally preferred designs without intrusions. However, intrusion became more tolerable when the overall shape is curved with preference ratings improved by 45%. This means that aesthetic evaluations of intrusions can be improved by changing the overall contour of the design. Under the angular condition, the intrusion effect was seen as more negative with participants preferring without-intrusion over with intrusion-by 20%. Interestingly, when the overall design was curved, the difference in ratings between with and without-intrusion dropped to 7%. We suspect that an intrusion within a shape might depict a sense of disturbance to the overall presentation of the shape; hence perceived as aesthetically unappealing. The same trend was observed in the interaction of angularity and edge angle. Angular designs with acute angles were less preferred with a mean rating of 3.7; their curved counterparts had a mean rating of 5.8, which is a 44% increase in preference ratings. Acute angles within a shape, especially in the angular form, resemble sharp objects and therefore can be perceived as threatening. With respect to designs with obtuse angles, preference ratings for curved designs increased by 33% compared to their angular counterparts. Angularity also had an effect on edge number; results revealed a strong preference for curved designs regardless of edge number. Differences in preference ratings were relatively large between angular and curved for all three levels of edge number. Angular designs with acute angles and with intrusions, as well as high in edge number were rated the lowest on the preference scale. A number of participants referred to this type of design as aggressive, angry, ugly, full of teeth, and monster-like.

When considering the effects that edge number has on preference ratings, results revealed that participants preferred designs with low edge number, followed by medium edge number, then designs with high edge number. Although the differences in mean ratings were fairly small, a general trend was observed. Contrary to existing literature, we found that preference decreased as edge number increased. This might be due to the levels of edge numbers used in the stimuli sets (low: 8, medium: 16, high: 24), in which a shape with a count of 8 edges might already appear to be visually complex. Thus, the 24 edge count might have already surpassed the preference threshold on the complexity-preference scale. Another explanation for this trend might be the differences in the experimental design as we included a number of other shape variables which could have overpowered the effect of edge number. Angularity, intrusion, and edge angle have all proven to have a stronger effect when considering the influences of shape manipulations on individual preference ratings. The interaction of edge number and edge angle further supported this trend; preference ratings decreased as edge number increased under both acute and obtuse conditions.

Another interesting discovery was the three-way interaction between angularity, edge number, and edge angle. Curved designs with obtuse angles and low edge number were most preferred by the participants, and angular designs with acute angles and high edge number were least preferred. The differences in preference for the two levels of edge angle were more pronounced in the three levels of edge number under the angular condition (low: 10%, medium: 18%, high: 21%). It is possible to conclude that the difference in preference between acute angle and obtuse angle will increase as edge number of the design increases. Designs with high edge number as well as acute angles can be visually perceived as "pointy" and "sharp", which can easily induce a sense of danger and threat resulting in low preference (Bar & Neta, 2006, 2007; Darwin, 1872; Larson et al., 2008, 2007; Silvia & Barona, 2009; Westerman et al., 2012). In the curved condition, the differences in preference between acute and obtuse angle in the three levels of edge number were much smaller (low: 6%, medium: 3%, high: 6%), with the difference between edge angle and medium edge number being insignificant. The reason for such finding might be that the degree of the angles within the designs became less distinguishable since the overall contour was curved.

3.4.2 Poster Rankings

Poster ranking results indicated a strong consensus in the category of least preferred designs, particularly in the context of harvest blocks. Results from both methods used demonstrate angular shapes with high and medium edge number, acute angles, as well as with intrusion were ranked as least preferred by the majority of the participants. For the harvest poster, three designs (#11, #54, and #74) selected as least preferred were identical in ranking from both methods. With respect to the shape poster, results from both methods revealed the same three designs, but slightly differed in ranking. The reason for such consensus can be related to our fear of sharp objects as they pose a sense of threat and danger; all three designs have sharp edges and intrusions. However, some participants ranked these three designs as their most preferred designs; existing literature suggest that this preference might be linked to personality and/or self-construal. A study led by Zhang, Feick, & Price (2006) examined the possible linkage between self-construal and aesthetic preference for rounded versus angular shapes. Results indicated that participants with independent self-construal perceived angular shapes as more attractive, whereas participants with interdependent self-construal rated curved shapes higher in preference (Zhang et al., 2006). Even though our results did not indicate an explicit relationship between aesthetic preference and self-construal; it indeed suggests that minorities – those who prefer angular shapes – exist, and this preference might be linked to their personality.

There seems to be less of an agreement in the categories of most preferred designs. Results indicated a strong preference towards curved shapes with low and medium edge number, obtuse angles, and no intrusion; especially in the context of harvest blocks. Again, the preference for curved shapes can be linked to a potential evolutionary advantage. However, it is intriguing to discover that design #5 (ranked as most preferred in method 1) is the curved version of design #54 (ranked as least preferred 2 & 3 in both methods). In other words, preference for the exact shape with the same features can be significantly increased by curving the outline of the shape.

3.4.3 Implications for Future Research

The findings of this study bring about four additional issues that require further investigation. First, further experiments need to be conducted to verify our findings pertaining to edge number. Our results indicate a decrease in preference as edge number increased, contrary to existing literature (Attneave, 1957; Berlyne, 1958, 1963; Day, 1967; Martindale et al., 1990). This experiment constrained the edge number levels within a small range at 8, 16, and 24. An experimental design with a larger range might produce different results. Other characteristics including angularity, intrusion, and edge angle had larger effects on preference; additional experiments could also investigate the edge number effect by further constraining these variables. Second, while we held the view angle of the designs constant, additional research must be conducted to confirm if these findings are consistent when seen from different perspectives. Moreover, it may also be worthwhile to investigate the impacts of these shape characteristics across a range of landscapes. Third, while the use of a 1-10 preference scale has proved to be effective in this experiment, this method may be subject to central tendency bias and social desirability bias. Future studies could adopt other methods such as forced-choice tasks to test for this. Lastly, there is a need to make connections between disciplines; for instance, parallels can be drawn between perception based studies focusing on landscape preference and visual perception research in the field of psychology. We could use such knowledge to our advantage in understanding human aesthetic evaluations of the environment and improve visual designs of the landscape.

This experiment provides perceptual results which can be directly linked to forest management. Results indicated a strong preference towards harvest blocks with curved contours with low to medium edge numbers. Operationally, this suggests that curved contours can reduce aesthetic impact and improve preference ratings. As demonstrated in the results, preference ratings can be improved by manipulating the contour of the shape while holding other variables constant. Therefore, it is important to note that perceptual gains can be achieved by curving the edges or the contour of the harvest block. These findings can be integrated into current forest management strategies, particularity in the design of harvest blocks. Curved shapes with low to medium edge numbers should be the method of harvesting, especially in visually sensitive areas.

The findings from this experiment certainly help in understand how shape characteristics can be used to influence aesthetic evaluations. However, additional research must be conducted to verify if these findings will persist across a range of landscapes. Although these results surely bring a number of challenges, it implicates that shape and its associated characteristics can influence the overall aesthetics of the landscape. The manipulation of certain shape attributes such as angularity, edge number, edge angle, and intrusion might shine some light on reducing the overall aesthetic impact of a landscape. Individual preference ratings can be improved by curving the edges or contour of the design; this effect was significant in both harvest and shape conditions. While there are many elements related to harvest block design, this study shows that shape can certainly play a role in the visual management of the forest.

Chapter 4: Conclusion

The primary objective of this thesis was to determine and quantify the effects of shape characteristics on individual aesthetic preference. The secondary objective was to investigate whether the presentation of shapes in different contexts (harvests vs. shapes) could influence preference ratings. The objectives were successfully addressed through an extensive literature review and the development and administration of two preference experiments. The findings presented in this thesis provide new insights to the visual management of forests and the field of aesthetics. The remainder of this chapter summarizes the most important conclusions from previous chapters, and synthesizes how these findings can improve VRM followed by possible directions to future research.

4.1 Summary of Conclusions

Chapter 1 presented a comprehensive literature review on visual preference indictors from two disciplinary areas including landscape aesthetics and psychology. This review provided the foundation of shape variables investigated in the two preference experiments. In experiment 1, the effects of context and complexity were explored. Context, angularity, edge number, edge angle, and intrusion were tested in experiment 2. The two experiments conducted also differed fundamentally in the methods used to develop the stimuli material. Images used for experiment 1 were developed based on aerial images of harvest blocks found in British Columbia. Whereas in experiment 2, shapes were developed first based on a number of shape parameters derived from psychology. In other words, experiment 1 was developed within the framework of landscape ecology while experiment 2 was developed from a psychological perspective.

Complexity was determined using the shape index metric from FRAGSTATS in experiment 1 and demonstrated the largest effect on preference. A monotonic relationship was detected between complexity and preference where preference ratings increased as the level of complexity increased. Although the majority of the literature focusing on complexity has found a U-shaped relationship (Berlyne, 1958, 1963; Day, 1967), similar experiments have indicated a positive linear function (Chamberlain & Meitner, 2012; Martindale et al., 1990). It is possible that preference will decrease if the experiment included higher complexity levels, though real life harvest blocks are unlikely to possess extremely high levels of complexity. In experiment 2, edge number was used as a measure of complexity, as demonstrated through existing research in psychology (Attneave, 1957; Day, 1967; Martindale et al., 1990). However, contrary to the literature, our findings suggested a preference tendency towards designs with low edge number. We suspect the reason behind such finding is the inclusion of other shape variables in the experimental design. Angularity, intrusion, and edge angle have all proven to have stronger effects on preference ratings than edge number. Edge number also interacted with a number of variables including context, angularity, and edge angle. Angular shapes with acute angles and high in edge number produced low preference, in both computer ratings and poster rankings. Some subjects commented and referred to these designs as “monster-like”, “aggressive”, and “angry”. It is possible that the effect of edge number has been overpowered by the effects of angularity and/or edge angle, where the subjects associates those mentioned negative traits with high levels edge number. This may implicate that edge number, perhaps should not be used as an indicator of complexity when it comes to harvest block design as it cannot represent all the qualities of complexity within a landscape. Although complexity (shape index and edge number) demonstrated different effects in the two experiments conducted, results still infers that complexity can be hold accountable in explaining individual aesthetic preference.

The effects of angularity, edge number, edge angle, and intrusion were tested in experiment 2. Overall, the strongest preference was given to curved designs with obtuse edge angles, without intrusion, and low in edge number. Angular designs with acute edge angles and intrusion as well as high in edge number were rated lowest in preference. Consistent with previous findings (Bar & Neta, 2006, 2007; Larson et al., 2008, 2007; Silvia & Barona, 2009; Westerman et al., 2012), our results indicated that subjects had a strong tendency to prefer both shapes and harvest blocks with curved contours rather than their angular counterparts. This preference maybe closely linked to the human evolutionary advantage as angular forms imply threat and danger (Darwin, 1872). Angularity demonstrated a considerably larger effect compared to all other variables tested. Moreover, angularity also interacted with a number of other variables including intrusion, edge angle, gender, order, and edge number. Designs without intrusion were rated higher in preference than designs with intrusions. We suspect that an intrusion within a shape might depict a sense of disturbance to the overall presentation of the shape, thus perceived as aesthetically unappealing. Designs consisting of obtuse edge angles were preferred over designs with acute edge angles. The reason for such preference tendency again, can be linked to the argument of evolutionary advantage; acute edge angles are perceived as sharp edge and thus pose a sense of danger. One important trend found was that the effects of intrusion, edge angle, and edge number can be reduced by the curving of the shape contour. Preference ratings increased in the curved condition for all these effects. The effect angularity prevailed through these interactions and appears to be robust.

Results from both experiments indicated the effect of context was significant. In experiment 1, the shape image set was rate higher in preference than their harvest counterpart with a small 2% difference. One possible reason for this finding is that harvest blocks, particularly clear-cuts are generally perceived negatively by the public (B.C. Ministry of Forests, 1996; Bliss, 2000; Chamberlain & Meitner, 2012; Sheppard, 2004). However, the harvest image set was rated higher in preference in experiment 2, thought the difference is less than 2%. The reason behind this effect is rather unclear. An interaction of complexity and context was also observed in experiment 1. In the context of harvest block designs, participants showed a lower preference for low complexity and a higher tolerance for greater complexity when compared to the shape condition. The reason for such result might be linked to the concept of naturalness where high complexity shapes in a forestry setting are seen as organic and natural, while highly complex shapes on paper may be perceived as complicated and unpleasant. Context also interacted with edge angle, intrusion, and edge number; where these variables had stronger effects on preference in the harvest condition than in the shape condition. This trend indicates that the aforementioned shape characteristics might be more effective predicting preference pertaining to landscape aesthetics than perceptual psychology.

Another relevant discovery found within experiment 1 was the effect of area of study and its interaction with complexity. Subjects were identified either as environmentally-focused or non-environmentally focused based on academic programs provided. Overall, mean ratings produced by environmentally focused subjects were lower than subjects with academic focuses on non-environmental fields by a small 2% difference. However, mean ratings of both groups differed significantly when levels of complexity was added. A positive linear relationship between complexity and preference was found in preference ratings given by environmentally focused subjects, while non-environmentally focused subjects indicated a stronger preference towards designs with medium levels of complexity. This outcome is likely a reflection of subjects' areas of study. Participants in environmental disciplines perhaps had a greater chance to perceive low complexity shapes negatively as they potentially resemble clear-cuts and may be perceived as more disturbing to the existing landscape. Furthermore, they might perceive highly complex shapes as more organic and natural resulting in higher preference ratings.

With respect to the inclusion of aerial view to VRM, subjects were required to state whether or not forest managers should expand visual management of the forest to include an aerial view. The majority (77% & 83%) indicated agreement with this statement. Although this finding alone cannot dictate a comprehensive conclusion, it might be worthwhile to investigate further.

4.2 Implications for Forest Management

Results from both experiments can be linked directly to forest management. Shape complexity, (experiment 1) demonstrated significance as an indicator of preference. This finding can be directly applied to forest management since the stimulus sets used were real harvest blocks. Subjects' expressed highest preference for designs with medium to high levels of complexity, with the difference between the two levels being statistically insignificant. This means that, for all intents and purposes, increased complexity in harvest block design in the context of forest management can typically be seen as a positive aesthetic variable. Operationally, the addition of medium level of complexity would be the best option as it can be more easily integrated into harvest design, resulting in low operational cost for a high perceptual gain. Whereas the addition of high levels of complexity can be difficult to construct. Results from the second experiment indicated that the curvature of the contour of shapes can improve preference ratings in both conditions, with it being more pronounced in the harvest condition. This finding implicates that aesthetic impact of harvest blocks can be reduced by curving the edges or the contour of the harvest block. In visually sensitive areas, curved designs with medium levels of shape complexity should be the preferred method of harvesting.

4.3 Limitation

Although this research has reached its aims, there were some unavoidable limitations. First, participants from both experiments were UBC students; therefore, it may be useful to test the reliability of the results with a more heterogeneous population sample. A meta-analysis of environmental aesthetic preference study was conducted by Stamps (1999) concluded that there is a very high degree of consensus in environmental aesthetics for many demographic distinctions. High correlation was found comparing students to a number of other groups. Lower correlation was only found for three demographic groups including children versus adults, special interest groups versus other people, and designers vs. non-designers. As forest managers often work with special interest groups; the inclusion of special interest groups in the sample would help in understanding the difference in preference between special interest groups and the general population. Second, the methodology used in categorizing subjects' area of study was problematic. Subjects were divided into non-environment focused discipline versus environment-focused discipline based on their faculty. However, this method might not be sufficient since faculty alone cannot be an adequate identifier for academic focus. For instance, some Engineering students might have an academic focus in forestry or resource conservation. Third, since both experiments were conducted in the Forest Sciences building, participants might already been biased before completing the computer survey and provide answers based on expectation. Finally, both experiments used a 1-10 preference scale to determine aesthetic ratings. While such rating scales are commonly used in experimental surveys, this method could be subjected to central tendency bias and social desirability bias.

4.4 Future Directions

The research presented in this thesis provides some ground work for the development of additional ways to assess aesthetics with respect to the visual management of forest resources as well as a few logical next steps in future research.

First, the effects of shape on preference should be investigated further from other perspectives. While the effects of context, angularity, complexity (edge number), edge angle, and intrusion have proven to be successful in predicting individual aesthetic preference; the view angle of the designs used was held constant. Thus, additional research must be conducted to confirm if these findings are consistent when seen from different perspectives. Perhaps the effects of perspectives pertaining to harvest block design can also be investigated.

Second, additional research is needed to explore the potential linkages between academic background and landscape aesthetics, as well as personality and landscape aesthetics. While the findings presented in this thesis suggested the "how" in human evaluations of the landscape, we did not consider the "why". Although a number of environmental psychologists have investigated the cause of certain aesthetic tendencies, linking it back to the evolutionary advantage, few have looked at the effects of demographic information such as education on preference. Results presented in this thesis suggest there might be a possibility in identifying such relationships. Results from experiment 1 on the effects of subjects' area of study offer interesting implications. Although the effect of area of study was small, it might be worthwhile to develop a more comprehensive experiment focusing exclusively on finding the relationship between academic background, personality characteristics and aesthetic preference. It is important to understand such connection and perhaps we could extend landscape aesthetics to the field of environmental education. Poster ranking results from experiment 2 demonstrated that minorities – those who prefer angular shapes – do exist; the ratings of this group differed significantly from their peers for reasons unknown. However, existing literature suggest that aesthetic preference for shapes might be linked to self-construal (Zhang et al., 2006). If such linkage exists, it will provide another pathway in understanding the complex relationship between human-landscape interactions.

Third, there is a need to make connections between disciplines. For instance, parallels can be drawn between perception based studies focusing on landscape preference and visual perception research in the field of psychology. Future studies need to be more interdisciplinary, predominantly in their methodologies; perhaps developing experimental methods addressing more than one discipline. We could use such knowledge to our advantage in understanding human aesthetic evaluations of the environment and improve visual designs of the landscape.

4.5 Concluding Remarks

The findings and insights presented in this thesis contribute to the understanding of how humans interact with, perceive and experience the landscape. Perceptual based research from both landscape ecology and psychology, along with computational landscape design were the foundation of these new discoveries. This research has resulted in the development of new information which may lead to more effective visual resource management, particularly in the aesthetic design of harvest blocks. This research has identified and quantified the effects of shape characteristics on harvest block design with respect to individual aesthetic preference. The findings presented can provide helpful information in public perception and preference of the landscape to forest designers and managers. Along with the ecological well-being of the landscapes, the maintenance of aesthetics is also critical in ensuring sustainable management of the forest and its valuable resources.

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Appendices

Appendix A: FRAGSTATS Metrics

AREA METRICS

(P4) Area	
$AREA = a_{ij}\left(\frac{1}{10,000}\right)$	a_{ij} = area (m^2) of patch ij.
Description	AREA equals the area (m^2) of the patch, divided by 10,000 (to convert to hectares).
Units	Hectares
Range	AREA > 0, without limit. The range in AREA is limited by the grain and extent of the image; in a particular application, AREA may be further limited by the specification of a minimum patch size that is larger than the grain.
Comments	The *area* of each patch comprising a landscape mosaic is perhaps the single most important and useful piece of information contained in the landscape. Not only is this information the basis for many of the patch, class, and landscape indices, but patch area has a great deal of ecological utility in its own right. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

(P5) Perimeter	
$PERIM = p_{ij}$	p_{ij} = perimeter (m) of patch ij.
Description	PERIM equals the perimeter (m) of the patch, including any internal holes in the patch, regardless of whether the perimeter represents 'true' edge or not (e.g., the case when a patch is artificially bisected by the landscape boundary when a landscape border is present).
Units	Meters
Range	PERIM > 0, without limit.

Comments	Patch *perimeter* is another fundamental piece of information available about a landscape and is the basis for many class and landscape metrics. Specifically, the perimeter of a patch is treated as an edge, and the intensity and distribution of edges constitutes a major aspect of landscape pattern. In addition, the relationship between patch perimeter and patch area is the basis for most shape indices.
(P6) Radius of Gyration	
$\text{GYRATE} = \sum_{r=1}^{z} \frac{h_{ijr}}{z}$	h_{ijr} = distance (m) between cell ijr [located within patch ij] and the centroid of patch ij (the average location), based on cell center-to-cell center distance. z = number of cells in patch ij.
Description	GYRATE equals the mean distance (m) between each cell in the patch and the patch centroid.
Units	Meters
Range	GYRATE ≥ 0, without limit. GYRATE = 0 when the patch consists of a single cell and increases without limit as the patch increases in extent. GYRATE achieves its maximum value when the patch comprises the entire landscape.
Comments	*Radius of gyration* is a measure of patch extent; thus it is effected by both patch size and patch compaction. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

SHAPE METRICS

(P7) Perimeter-Area Ratio	
$$PARA = \frac{p_{ij}}{a_{ij}}$$	p_{ij} = perimeter (m) of patch ij. a_{ij} = area (m^2) of patch ij.
Description	PARA equals the ratio of the patch perimeter (m) to area (m^2).
Units	None
Range	PARA > 0, without limit.
Comments	*Perimeter-area ratio* is a simple measure of shape complexity, but without standardization to a simple Euclidean shape (e.g., square). A problem with this metric as a shape index is that it varies with the size of the patch. For example, holding shape constant, an increase in patch size will cause a decrease in the perimeter-area ratio.

(P8) Shape Index	
$$SHAPE = \frac{p_{ij}}{\min p_{ij}}$$	p_{ij} = perimeter of patch ij in terms of number of cell surfaces. min p_{ij} = minimum perimeter of patch ij in terms of number of cell surfaces (see below).
Description	SHAPE equals patch perimeter (given in number of cell surfaces) divided by the minimum perimeter (given in number of cell surfaces) possible for a maximally compact patch (in a square raster format) of the corresponding patch area. If a_{ij} is the area of patch ij (in terms of number of cells) and n is the side of a largest integer square smaller than a_{ij}, and $m = a_{ij} - n^2$, then the minimum perimeter of patch ij, min-p_{ii} will take one of the three forms (Milne 1991, Bogaert et al. 2000): min-p_{ii} = 4n, when m = 0, or min-p_{ii} = 4n + 2, when $n^2 < a_{ij} \leq n(1+n)$, or min-p_{ii} = 4n + 4, when $a_{ij} > n(1+n)$.
Units	None
Range	SHAPE ≥ 1, without limit. SHAPE = 1 when the patch is maximally compact (i.e., square or almost square) and increases without limit as patch shape becomes more irregular.
Comments	*Shape index* corrects for the size problem of the perimeter-area ratio index (see

	previous description) by adjusting for a square (or almost square) standard and, as a result, is the simplest and perhaps most straightforward measure of overall shape complexity. Note, the minimum perimeter for an aggregate of like-valued square pixels (a_{ij}) is calculated as above. For large patches, say $a_{ij} > 100$ pixels, the minimum perimeter asymptotically approaches $4\sqrt{a_{ij}}$, the perimeter of an exact square of size a_{ij}. Previous versions of FRAGSTATS used this large patch approximation in the shape index. Thus, the results will not agree exactly with previous runs, although the differences will be nontrivial only in cases involving very small patches.

(P9) Fractal Dimension Index	
$FRAC = \frac{2 \ln (.25\, p_{ij})}{\ln a_{ij}}$	p_{ij} = perimeter (m) of patch ij. a_{ij} = area (m^2) of patch ij.
Description	FRAC equals 2 times the logarithm of patch perimeter (m) divided by the logarithm of patch area (m^2); the perimeter is adjusted to correct for the raster bias in perimeter.
Units	None
Range	$1 \le FRAC \le 2$ A fractal dimension greater than 1 for a 2-dimensional patch indicates a departure from Euclidean geometry (i.e., an increase in shape complexity). FRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters.
Comments	*Fractal dimension index* is appealing because it reflects shape complexity across a range of spatial scales (patch sizes). Thus, like the shape index (SHAPE), it overcomes one of the major limitations of the straight perimeter-area ratio as a measure of shape complexity.

(P10) Linearity Index	
$LINEAR = \frac{\left[\frac{a_{ij}^*}{(2b-r)^2}\right] - 1}{a_{ij}^*}$	a_{ij}^* = area of patch ij in terms of number of cells. b = average cell value of the medial axis transformation (MAT) of a patch. r = 0 if the MAT skeleton contains side-by-side rows; 1 if not.
Description	LINEAR equals the area of the patch (in number of pixels) divided by 2 times the average value of the MAT skeleton minus 0 if the MAT skeleton contains side-by-side rows, 1 if not, quantity squared, minus 1, over the area of the patch (in

	number of cells).
Units	None
Range	0 ≤ LINEAR < 1 LINEAR = 0 for square patches and approaches 1 for large patches which are all edge. Dividing by patch area normalizes the index since the maximum possible value of the numerator for a patch equals its area (when b = 1).
Comments	*Linearity index* (Gustafson and Parker 1992) is based on the medial axis transformation (MAT) of the patch. Note, this index is not influenced by patch size.

(P11) Related Circumscribing Circle	
$CIRCLE = 1 - \left[\frac{a_{ij}}{a_{ij}^{s}} \right]$	a_{ij} = area (m^2) of patch ij. a_{ij}^{s} = area (m^2) of smallest circumscribing circle around patch ij.
Description	CIRCLE equals 1 minus patch area (m^2) divided by the area (m^2) of the smallest circumscribing circle. Note, the smallest circumscribing circle is computed mathematically based on the geometry of a true circle, despite the raster data format. In addition, to ensure that the minimum value is always zero, the diameter of the circumscribing circle is computed as the maximum distance between periphery cells based on outer edge-to-outer edge distance, as opposed to cell center-to-cell center distance used in all nearest neighbor calculations.
Units	None
Range	0 ≤ CIRCLE < 1 CIRCLE = 0 for circular patches and approaches 1 for elongated, linear patches one cell wide. CIRCLE = 0 for one cell patches.
Comments	*Related circumscribing circle* (CIRCLE) uses the smallest circumscribing circle instead of the smallest circumscribing square despite the raster data format because it is much simpler to implement. In contrast to the linearity index, related circumscribing circle provides a measure of overall patch elongation. A highly convoluted but narrow patch can have a high linearity index if the medial axial skeleton is close to the patch edge, but have a low related circumscribing circle index due to the relative compactness of the patch. Conversely, a narrow and elongated patch can have a high linearity index as well as a high related circumscribing circle index. This index may be particularly useful for distinguishing patches that are both linear (narrow) and elongated.

(P12) Contiguity Index	
$$CONTIG = \frac{\left[\frac{\sum_{r=1}^{z} c_{ijr}}{a_{ij}}\right] - 1}{v - 1}$$	c_{ijr} = contiguity value for pixel r in patch ij. v = sum of the values in a 3-by-3 cell template (13 in this case). a_{ij} = area of patch ij in terms of number of cells.
Description	CONTIG equals the average contiguity value (see comments) for the cells in a patch (i.e., sum of the cell values divided by the total number of pixels in the patch) minus 1, divided by the sum of the template values (13 in this case) minus 1. Note, 1 is subtracted from both the numerator and denominator to confine the index to a range of 1
Units	None
Range	$0 \leq$ CONTIG ≤ 1 CONTIG equals 0 for a one-pixel patch and increases to a limit of 1 as patch contiguity, or connectedness, increases.
Comments	*Contiguity index* assesses the spatial connectedness, or contiguity, of cells within a grid-cell patch to provide an index of patch boundary configuration and thus patch shape (LaGro 1991). CONTIG is quantified by convolving a 3x3 pixel template with a binary digital image in which the pixels within the patch of interest are assigned a value of 1 and the background pixels (all other patch types) are given a value of zero. A template value of 2 is assigned to quantify horizontal and vertical pixel relationships within the image and a value of 1 is assigned to quantify diagonal relationships. This combination of integer values weights orthogonally contiguous pixels more heavily than diagonally contiguous pixels, yet keeps computations relatively simple. The center pixel in the template is assigned a value of 1 to ensure that a single-pixel patch in the output image has a value of 1, rather than 0. The value of each pixel in the output image, computed when at the center of the moving template, is a function of the number and location of pixels, of the same class, within the nine cell image neighborhood. Specifically, the contiguity value for a pixel in the output image is the sum of the products, of each template value and the corresponding input image pixel value, within the nine cell neighborhood. Thus, large contiguous patches result in larger contiguity index values.