Human Preference and Fractal Dimension

- An investigation in the possible connection between
fracal dimension and preference in human judgment
of swedish pastoral landscapes

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Förord

Vad gör att vissa mönster upplevs som krävande och andra som behagliga? Finns det ett samband mellan konturer i miljöer vi lever i och preferensen vi har för dessa miljöer? Dessa frågor har väckt min nyfikenhet och får stå som grund för att min artikel handlar om just preferens och konturer i miljöer och hur vi eventuellt kan kategorisera dessa utifrån en analys av fraktal dimension.
Att undersöka hur människan processar den information hon bokstavligt talat bombarderas med varje sekund i den omgivning hon befinner sig i är för mig en upptäcktsfärd som lockat mig i flera år. De eventuella svar som kan komma ifrån sådana undersökningar, må de vara estetiska, konstnärliga eller naturvetenskapliga, kommer att kunna vara behjälplig för landskapsarkitekter, arkitekter och designers. Någon gång då och då kanske de till och med kan tända en gnista av nyfikenhet hos någon som har ännu större resurser att utforska just någon speciell del i det vi kallar kognitionsvetenskap eller miljöpsykologi.

En kandidatuppsats kan ta många former och utvecklas olika beroende på vem det är som skapar den. I mitt fall kommer utformningen av uppsatsen naturligt av att jag är säker i mitt författande av vetenskapliga papers och artiklar, om än något ringrostig. Arbetet kunde säkert ha tagit en annan form, ett undersökande arbete, introspektivt eller med en utställning hade nog varit möjligt om jag haft dubbelt så mycket tid till förfogande. Uppsatsen har tagits fram genom att under hösten 2008 bearbeta och arbeta fram en kursplan för den individuella kursen som krävdes för att arbetet skulle kunna genomföras.
Under våren 2009 utfördes större delen av litteraturbearbetningen, både informationssökandet och struktureringen av tidigare forskning. Även de försök och analyser som är förutsättningarna för den diskussion artikeln behandlar har verkställts under våren. Detta skedde parallellt med att en annan kurs gick på halvfart, något som inte varit helt optimalt vid alla tillfällen, då mycket av arbetsflödet blev hindrat.
Vidare har själva skrivarbetet främst utförts under våren senare del, samt en del korrigering och tillägg skrivits under senare delen av sommaren.

Vid tangentbordet, någonstans mellan Lund och Alvesta den 23 augusti 2009.

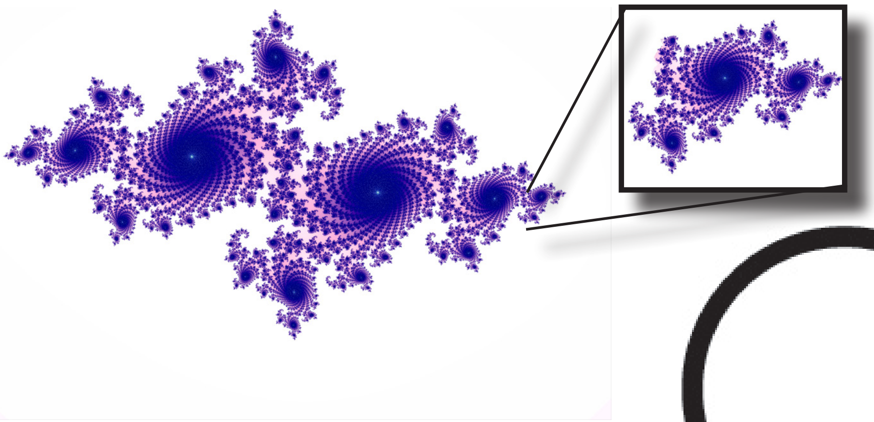
Abstract

The objective of this study is to assess any connections between the fractal dimension of edges in images of pastoral landscapes in Sweden and preference rating of the images and preference ratings for the edge images respectively.
23 participants volunteered for the trial. The mean age was 29,95 years, six of the subjects where women. The study consited of analysis of fractal dimension in images of pastoral landscapes from an earlier study and an experiment with human participants. The subjects estimated their preference for manipulated images, edge images, of pastoral landscapes. Their results where compared to results from the earlier study on non manipulated images.
The result show that significant connection exists and in a way that correlates well with earlier studies. The edge images did not have significant correlation. Results for the edge images: (r_s = 0.015, $p<0.0001$), and the original images: (r_s = -0.853, $p<0.0001$).
Furthermore the study discuss the concept “preference” and however that concept needs to be more defined if it is to be useful.

Introduction

To learn what humans prefer and what makes the environment preferable is crucial for the continued prosperity of our cities and their inhabitants. To learn how human preference is affected by stimulus has become more and more important because of the great assembling of humans in cities, where all of the surroundings are constructed. One part of this is to investigate what role the natural occurring fractal properties of the visual environment plays in affecting preference.

The name fractal comes from the Latin word fractus that means ”to break” (Mandelbrot, 1982, p 4). Before Mandelbrot gave the functions that create these mysterious patterns the name fractals, the geometric shapes that could not be explained by equations where called Monster curves (Carlsson, p 19.) by the mathematicians. Mandelbrot brought a change in thinking: The fractal is defined as a set calculated by an algorithm that is repeated several times, thus differentiating it from the euclidean geomterics of the circle and the square, that are explained by one equation. Further on the fractal is scale invariant in contrast to Euclidean geometry that has scale variance. This is easy to comprehend when comparing a part of a circle and a part of the Julia set for example. The circle changes when one ”zooms in” on the part in question, whereas the Julia set repeats itself (Carlsson, 1992).



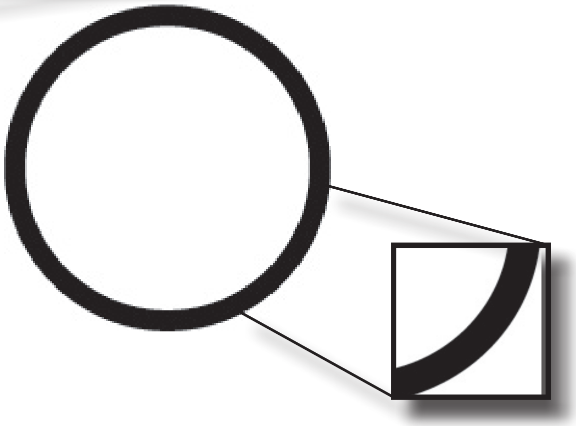


Figure 1 and 2. The circle is scale variant, the segment has different characteristics than the whole. The Julia set is scale invariant, a subset of the image has the same characteristics as the whole. The image of the Julia set is from the wikipedia commons and the circle is made by the author.

Another way to define fractals is by its dimension. Dimension is defined with the following relation(N being numbers of squares, L the length of the side of the squares and D being the dimension):

$N=L^{-D}$

This relation is then tested for several different lengths of sides of the squares covering an object. A square with the side 1 is the same as 4 squares with the side 0.5 and 16 squares with the side 0,25. This gives us a dimensional value of D = 2. That is the same as the dimensional value we usually give an object that covers a surface.

This gives us a expression for the dimensional value that looks like this:

$D = \log N / \log (1/L)$

(Carlsson, 1992, Taylor 2009)

This value can be calculated for images by using a method called box counting.
By masking the image with a mesh of boxes of a certain size and counting the boxes that contain any information (in black and white images, that contain something black), and then repeatedly masking the image with a smaller box size, we can calculate the fractal dimension. A fractal will increase in complexity (more boxes will contain information) as the box size decrease, and therefore if plotted in a logarithmic graph, the plots will have a positive slope. The power of this slope is the fractal D.
(Taylor 2009).

As an example we look at a square with a side length of 1.
as a first step we place a grid over the square, the mesh hole (box) size is half of the side of the square, 0,5.
Then we count the amount of boxes that covers the square, completely or partially. In our example we get four boxes that cover the square.
The next step is to decrease the size of the boxes to half the side length of that we had in before (0.5/2 = 0.25). Then we count the number of boxes needed to cover the square, this time they are 16.
We repeat this one more time, just to make sure we understand the theory. This time we decrease the side of the box side by half to 0.125 (0.25/2). Then we count the amount of boxes needed to cover the square, just like the two times before. This time we count to a total of 64 boxes covering the square, see figures 3 to 5 for clarification.

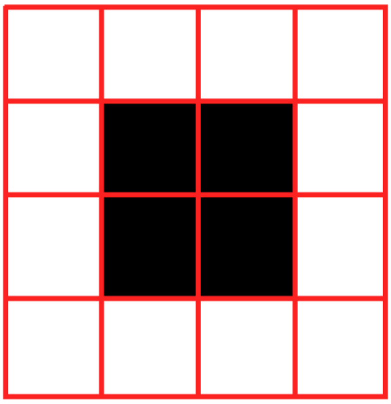


Figure 3. The image has been covered in squares with a side half of that of the object.

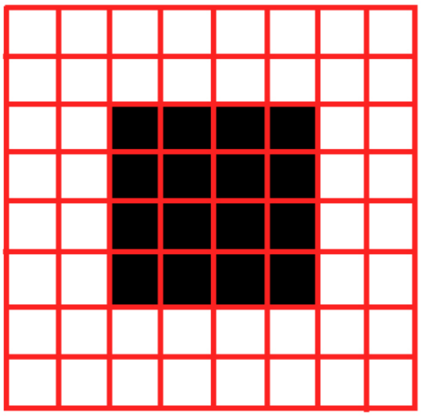


Figure 4. The image has been covered in squares with a side 25% of that of the object.

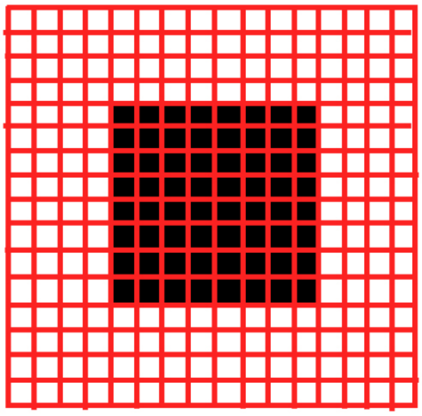


Figure 5. The image has been covered in squares with a side 12,5% of that of the object.

To calculate the dimension of the square, as we might suspect to be of a dimension of 2, we use the formula described above for every step we have gone through. If we are correct in our suspicion that the square should have a dimension of 2, we will get that same answer at every calculation.
The first calculation gives us as follows:

D = log (N)/log (1/L), D = log(4)/log(1/0.5) = 2
So long all is well. Euclid was right for the square for now.
Next step:
D = log (N)/log (1/L), D = log(16)/log(1/0.25) = 2
It is looking good for Euclid.
The last step:
D = log (N)/log (1/L), D = log(64)/log(1/0.125) = 2
Hereby, and by using other examples, we can establish that the box counting method is reliable to calculate the dimension of an object that is suppose to have a dimensional value between 0 and 2. To calculate an object with a dimension greater than 2, we need to use a cube counting method, but the principle is the same.
The same principle is used when calculating fractal dimension. The value then takes a non integer value somewhere in between 1 and 2.

For some time the idea that a certain amount of complexity in the visual surroundings appeal to people and provide the human brain with just enough stimuli to keep the observer from increasing stress levels, resulting in a relaxed focused state (e. g Kaplan & Kaplan 1989, Hägerhäll et al 2008). Kaplan and Kaplan, who presented a theory of human preference in their book The experience of Nature (Kaplan & Kaplan, 1989). In the book they present a model of preference that they call the preference matrix, where four conceptual words are used to describe a locations preference. These words (Coherence, Complexity, Legibility and Mystery) are in fact mostly dependent on the human visual system and therefore closely linked to any visual analysis of images. In the book it is claimed that the most prefered environments have qualities that puts Coherence and Complexity in equilibrium and the more of Mystery and Legibility that is estimated to be present, the more prefered the environment is (ibid, p. 58).
However very few have tried the correlation between the fractal dimension of an image and the preference for the same image. Hägerhäll et al(2004) showed that there is a significant correlation between preference and the fractal dimension of the horizon in images of landscapes. Cooper and Oskrochi (2008) conclude that there is a correlation between the fractal dimension and peoples subjective judgment on visual variety in series of photographs taken on a walk down a street. Other studies include the influence of fractal dimension on street edges on urban character (Cooper, 2005)
These studies have led to a theory forming that fractal dimension in images are influencing human preference judgment.

How then is fractal geometry influencing human preference?
A Electroencephalographic(EEG) study (Hägerhäll et al, 2008) have shown that fractal images creates a increase in alpha waves in the frontal lobes, and higher beta waves in the parietal lobes. This may connect to what Kaplan and Kaplan calls relaxed attention. Joye(2007) gives an interesting link between the two when describing that fractals are in themselves fascinating without demanding effort(p. 151).

This gives that if the statement that almost all natural environments has statistical fractal properties and that human preference is based on the visual properties of the environment, then the fractal properties might influence preference for that environment.
Studies show that people prefer images with a fractal dimension in the interval 1.3-1.5(Spehar et al, 2003). The theoretical explanation of this is that many patterns in natural images has a fractal dimension that is part of the 1.3-1.5 interval. This is not however the grand unification theory of aesthetics as for instance the golden ratio but instead a interesting statistical find that needs more exploration. This is mainly because the actual ingredients and composition of two images with the same dimensional value can differ significantly, as seen in figure 6 to 8.
One way of investigating this would be to assess the fractal dimension for the image surfaces of a sample of images and do an analysis of how this correlates to the preference rating of the same images as well as the actual image.

Figure 6. Image from Hägerhälls study (1999) with the fractal dimension 1.694.

Figure 7. Potograph taken in Kungsträdgården, Sweden, with the fractal dimension 1.687.

Figure8. Image from Hägerhälls study (1999) with the fractal dimension 1.681.

The goal of this study is to assess any connections between the fractal dimension of edges in images of pastoral landscapes in Sweden and preference rating of the images and preference ratings for the edge images respectively.

Method

The images used in this study comes from an earlier study done by Caroline Hägerhäll(Hägerhäll,1999). The original set of images consisted of 60 images, accompanied by mean preference values obtained from Hägerhälls study.
To limit the current study I picked out every other image, sorted by preference. This to make sure that I have the whole span of earlier preference values in my set. This gives a set that envelope the entire range of preference values in the earlier study.
The images used from Hägerhäll are availiable in Table 1.

ImageNr:	1	2	6	7	8	9	11	12
PreferenceValue, Hägerhäll	3,53	3,57	3,92	4,06	2,71	3,75	2,92	3,12
PreferenceValue, Pihel	4,1	3,8	2,35	3	2,85	2,9	2,5	3,1
Fractal D	1,725	1,603	1,585	1,533	1,574	1,479	1,602	1,662

ImageNr:	30	33	35	38	40	41	42	46
PreferenceValue, Hägerhäll	3,78	3,73	2,82	4,26	4,08	3,39	3,7	3,72
PreferenceValue, Pihel	3,45	3	2,5	3,25	3,7	2,41	3,95	3,05
Fractal D	1,681	1,572	1,693	1,662	1,615	1,597	1,493	1,656

Table 1. Overview of what images from Hägerhäll (1999) that was used in this study, the preference value Hägerhäll obtained, the preference value obtained in this study and the fractal dimensional value calculated in this study.

To be able to do a analysis of fractal D-value, the images had to be manipulated. The software used was GIMP 2.4.6 on the same computer that is described in the Apparatus section.
The images have been scanned from analogue color slides with a color depth of 16 bits. GIMP supports a color depth of 8 bits and therefore the color depth of the images was decreased to 8 bits, since the color depth has little importance in assessing fractal dimension of an image.
Thereafter the contrast and brightness of the images where manipulated to reduce noise in the image. Otherwise the noise might be a source of error in calculation the fractal dimension. The contrast where set to max (a value of 127 in GIMP) and the brightness value where set to 50% of the original (a value of 64 in GIMP).
Then the edges were calculated by the software's (GIMP) embedded edge detection algorithm (A sobel based algorithm with an amount set to 1.0 and smeared (the difference between Wrap, Smear and Black had no significant difference when calculating the fractal dimension later on).
The procedure is shown in Figures 9 to 13.

Figure 9. A sample of the original images from Hägerhäll (1999).

Figure 10. The color is reverted to grayscale.

Figure 11. The contrast and brightness is adjusted to eliminate most of the noise in the image.

Figure 12. Edge detection done by GIMP.

Figure 13. The image has been inverted to be compatible with the fractal calculation program Fractalyse.

The fractal dimension was calculated with the software Fractalyse, using the same settings as Hägerhäll et al (2004), box counting at an exponential interval of 4 to 882 pixels.
The hardware that was used to calculate the images and expose the subjects to the images was a laptop computer with a 17” monitor (DELL precision M6300, Intel Core 2 Duo T9300 @ 2,50GHz, 4 GB RAM, nVIDIA Quadro FX 1600M with 256 MB GDDR3 memory graphics) with a resolution of 1920x1200 pixels.
The software used to manipulate the images was GNOME 2.22.3, and the software used to display the images was Eye of GNOME 2.22.3.

The subjects where exposed to the edge images, not the original color photographs.
The images where sorted in accordance to the preference value from Hägerhäll(1999) and the subjects controlled the duration of each exposure using the keyboard of the computer. Half of the participants where exposed to the images starting with image number 30 and ending with image number 1, in order and the other half started with image number 1 and ended with image number 30, in order. That ensured that half of the subjects where exposed to the series of images with increasing preference value from the previous study, and the other half where exposed to a decreasing preference value from the previous study.
The subjects got to answer the question “How much do you like the environment that is depicted?” (in swedish “Hur mycket tycker du om miljön som avbildas?”) and got to give their answer on a five graded scale where 1 was “not at all”(in swedish “inte alls”), 2 was “little” (in swedish “lite”), 3 “undecided” (in swedish “varken eller”), 4 “some” (in swedish “mycket”) and 5 “a lot” (in swedish “väldigt mycket”). The subjects noted their answers on a form with a pen. The form, in swedish, is found in appendix 1.
To motivate the participants there were an offering of a cup of coffee and a cookie when they finished the trial.

Results

A total of 23 participants volunteered for the trial. Two other subjects results where eliminated due to incorrect marking of the answers on the forms. One subjects results where eliminated due to bias in viewing of landscapes (trained artist). Included in the study where the remaining 20 subjects. The mean age where 29.95 yrs, six of the subjects where women. Subjects 2-5 originated from the town of Ljusdal, subjects 1 and 6 – 23 carried out the study at Malmö University. The Spearman rank correlation coefficient for the fractal dimension and the preference values for the manipulated images showed that almost no correlation exists between the two variables ($r_s =$ 0.015, $p<0.0001$). However, the rank correlation coefficient for the fractal dimension of the images and the preference values from Hägerhäll et al(2004) showed a strong negative correlation between the two variables ($r_s =$ -0.853, $p<0.0001$). This shows that preference increase as the fractal dimensonal value decreases.

Discussion

The study presented here has two results to communicate. The first result is from the correlation between fractal dimension and earlier data on preference that has been received by subjects that viewed the original image(data source as described earlier). These results show a strong negative correlation between preference and fractal dimension(preference ratings increase as the fractal dimension decreases). Since the correlation is very strong and negative, these result supports earlier research that stipulates that human preference is connected to a fractal dimensional value between 1.3 and 1.5. Dimensional values outside this interval should give a lower preference value as suggested by for instance Spehar et al (2003) among others. The results of this study could support the notion of preference peaking at 1.3, due to the fact that a strong negative relation is found for images with dimensional values in the interval from 1.479 to 1.725. A study that involved pastoral images with greater span in dimensional values might shed more light on this.

Secondly, the trial to assess if preference for images of pastoral landscapes that were manipulated to only show the edges that is used to calculate fractal dimension correlates to preference for the original images. This resultcould be explained by to much information is removed during the process of manipulation that the end result is no longer a representation of the original image.

The removal of color, shade, etc from the images, removes the clues to what kind of place the image represents. Some of the participants added to this idea when they exclaimed during the test that they could not see what the image was representing, not even if it was a place or just some abstract drawing. Even though it is fairly obvious that information about shade, color and so on affects the human preference judgment, there is very little material that shows us exactly how such information affects preference ratings. This could be explained to some extent by the simple fact that color adds so many uncontrolled variables that it is almost impossible to draw any scientific conclusions from it.

The fact that there was a significant connection between the preference rated by Hägerhäll (1999) and the fractal dimension calculated in this study, but no significance between preference in the manipulated images in this study and the fractal dimension of the images support the above.

How can a mathematical notion such as fractal dimension be a good indicator of human restorativeness in environment? One theory is that fractal patterns in the environment harmonizes with the neuronal setup in the human brain, and the patterns read from neuronal activity. Joye Jannick gives an example in his doctoral thesis (2007) where he shows us incidents where neuronal activity in the visual cortex was significantly increased when the subjects where exposed to fractal patterns (Joye 2007, p. 155). On the other hand this effect might just consist of the V1 areas innate function of resolving edges of objects(Gazzanigia et al. 2002, p.155).

Could it be that a certain fractal D value enables the soft fascination that Kaplan, Kaplan and Ryan (1998) presented? They found that preference rating for some landscapes were significantly lower than others. These were the images of large expanding landscapes almost without any variation and the other group where a group of images with dense vegetation.
This find is related to the images fractal D value. The flat land images would have a D value close to 1, whereas the dense vegetation images would approach a D value of 2. To even further strengthen the idea of fractal D value as a indicator for preference, they found that images with trees spaced with a certain distance that gives an impression of shelter without blocking any view, and level ground got the highest scores in their preference study. This matches the theory of fractal D as indicator of preference, since such images of landscapes might get a fractal D value of around 1.3-1.5. This statement would be interesting to try empirically, using a fractal analysis as for example the one in this study to analyse the images used by Kaplan, Kaplan and Ryan.

As Taylor et al (2005) points out:

> *"Although D is just one of a number of parameters required to convey the visual information of the images used in these experiments, D appears to be central to establishing aesthetic preference."*

This reconnects to my point in the introduction that fractal dimension can not be treated as THE solution of all landscape assessment. Fractal dimension is one of many approaches to attempt to measure naturalness, and therefore only a tool for us to use, not a law to follow blindly.
But on the other hand, just as Taylor et al(ibid) argue, it seems that fractal properties in images have a strong connection to the experience of the images. Purcell et al (1994) discuss the issue of what exactly we measure when we claim to measure preference. In the article from 1994, Purcell et al. brings forward that even if the image of the landscape is the same, the subjects earlier experiences many other factors that plays a role in the subjective judgement of preference for different scene types. They also raise the importance of the possibilities of the scene, and this affects the subjects preference. These issues is important to have under control when asking for peoples preference, since there is a difference between such a simple thing as preference to live in a place and to visit as a tourist.

The present work has not taken this into account, yet the result of this study shows that there is a common ground for preference, in some aspect, and fractal dimension. However, the term preference might need to be subject to a more thorough work to define it in some way, maybe by differentiation between different types of preference as Purcell et al (1994) suggests.
As preference might me a mix of genetic predispositions and earlier experiences the connection to fractal patterns might be a learnt attribute. Since humans have vision as the dominant sense (Boroditsky, 1999) we can assume that we from an early age are conditioned by the visual environment. This might give a part of an explanation to why fractal properties influence human preference, since most visual occurrence in biological and geological phenomena have self similarity and therefore have fractal statistical properties. This also suggests that by measuring the fractal dimension, we actually can quantify the term "naturalness" (e.g. Hägerhäll et al, 2004).
Ode et al (2009) has found an interesting model for how different aspects of these occurrences might interact. In a grid with two axis, where one has fractal properties in one end, and sinuous properties in the other. The other axis has Euler characteristics and Number of branches as extremes. Ode et al suggests that these properties all affect human preference and therefore preference judgments needs to be calculated with all these in mind and included in the theoretical model for landscape preference.

Is there any use in doing these investigations?
Purcell et al. later study from 2001 connects preference to restorative environments. Their work suggests that preference and restorativeness of a place is correlated . They however stipulate that there is no empirical evidence to support that fractal properties has anything to do with preference.
I would not go that far, but there is still work to be done if we are supposed to be able to declare a clear connection between the two. Purcell et al raises an interesting point however,that there might be a connection between restoration and fractal properties of the environment with preference acting as the middle man. This is however only speculations by me and others, but as more and more work is done that shows similar results, there is more and more empirical data to back up these theories.
The notion that fractal properties, foremost of images with a fractal dimension in the span between 1.3 to 1.5, may be involved in creating the state Kaplan and Kaplan calls relaxed attention is interesting on its own. Joce (2005) makes the observation that earlier research has shown that human stress recouperation is increased when subjects are exposed to fractal images. There is indeed a lot of work to be done in this area of research and a lot to find about the connection between human preference and the fractal dimension of the prefered environment.

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Appendix 1

The following pages are showing the form that was used by the subjects in the study.