i) [illegible] inversion, response parametric hypothesis [illegible], but still [illegible] in [illegible] consequences for rectangle

ii) Theory will account for isosceles triangles / [illegible]

iii) Theory accounts for general preference for symmetry

iv) Taylor ([illegible] Amer) [illegible]

AN EXPERIMENTAL ANALYSIS OF AESTHETIC RESPONSES OF HUMAN SUBJECTS TO RECTANGLES

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§1.1 Introduction

Aesthetics represents an enormous problem for contemporary psychology in that there is virtually no theory at all to explain why subject's will judge some items to be beautiful and others to be ugly. Indeed we are not even sure how constant these judgments are over a period of time, although inferential evidence such as the continuing popularity of certain works of art suggests that some constant factors may be present.

How may one start to analyse this problem in an experimental manner? One simple way is to take a single stimulus dimension, to vary the stimuli upon this dimension, and to find which of the stimuli are preferred. Such a technique has been applied to colour preferences both in man [15] and in monkeys [28].

Colour however is a very obvious dimension to use, it being easily quantified if need be, and the dimension itself being immediately apparent. However form is also a variable of great importance in the perception of beauty and yet it consists of a multitude of dimensions. The approach to the problem in this project has therefore been to take a single geometrical shape, the rectangle, and to vary it along the dimension of the ratio of the longer side to the shorter side, whilst keeping the area constant.

The reason for choosing this particular stimulus dimension is that an enormous amount of literature has already been produced on the beauty or otherwise of rectangles, and there would seem to be a large number of inconsistencies in the data already obtained (see §2.4).

Throughout this report reference will be made to the ratio of a rectangle, the orientation of a rectangle, and the Golden Section (or Golden Mean) rectangle. These are defined as:-

- The ratio of a rectangle represents that figure obtained by dividing the length of the horizontal side by the length of the vertical side. This value therefore has the range of zero to infinity. This is an impractical scale to use in many ways and therefore reference will also be made to the logarithm (always to the base 10) of the ratio; this measure has the advantage that the log.ratio of a square is zero, whilst the action of rotating a rectangle through 90 degrees merely alters the sign of the log.ratio leaving the numerical value the same; thus a rectangle 10 cms by 4 cms has a ratio of either 2.5 or 0.4 according to which edge is horizontal; however the log.ratio is either 0.398 or -0.398 according to which edge is the longer. This method also has the advantage that it is probably more genuine perceptually e.g. on a linear scale the difference between a rectangle of ratio 1.5 and one of ratio 1.6 is very much greater than one of 4.0 and one of 4.1, whilst the difference between rectangles of log.ratio 0.5 and 0.6 is equivalent to a pair of rectangles of log.ratios 3.0 and 3.1 (i.e. it is probable that a Weberian type relationship holds).

- The orientation of a rectangle is defined as either vertical, horizontal or square. A vertical rectangle is one in which the ratio is less than 1 or the log.ratio is negative. A horizontal rectangle has a ratio of greater than 1. and a log.ratio whch is positive. A square has a ratio of 1.0 and a log.ratio of 0. . In the rest of this report in order to maintain consistency the results of other workers will be transformed into this convention in order to avoid confusion.

- Golden Mean rectangle. This is a particular rectangle with special properties, consider the rectangle in Figure 1.1 :-

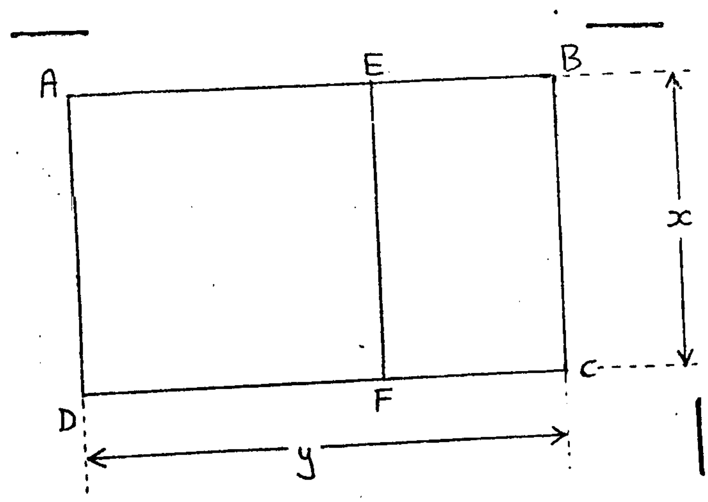


Figure 1.1
Golden Section rectangle

ABCD represents a rectangle. The property of the Golden Section rectangle is such that if a square, AEFD, is removed from one end then the rectangle which is left, EBCF, has the same proportions as the original rectangle, ABCD.

Mathematically therefore, since EB = y - x :-

$$\frac{y}{x} = \frac{x}{y - x}$$

If only the relative proportions of the rectangle are required then it is reasonable to substitute y = 1

$$\therefore \frac{1}{x} = \frac{x}{1 - x}$$

$$\therefore x^2 = 1 - x$$

$$\therefore x^2 + x - 1 = 0$$

Solution of this quadratic yields the result, x = 1.618 or 0.618, or $\log_e(x)$ equals either +0.21 or -0.21 .

This rectangle has several other properties although for the present purpose this one is the most important. Other properties include the fac that the process may be continued on the remaining rectangle, EBCF, ad infinitum. The net result of such an action is to obtain a 'right angled logarithmic spiral' (See Figure 1.2), a form which is consistently found in nature [8]. The number 1.618 also has many other strange properties [43].

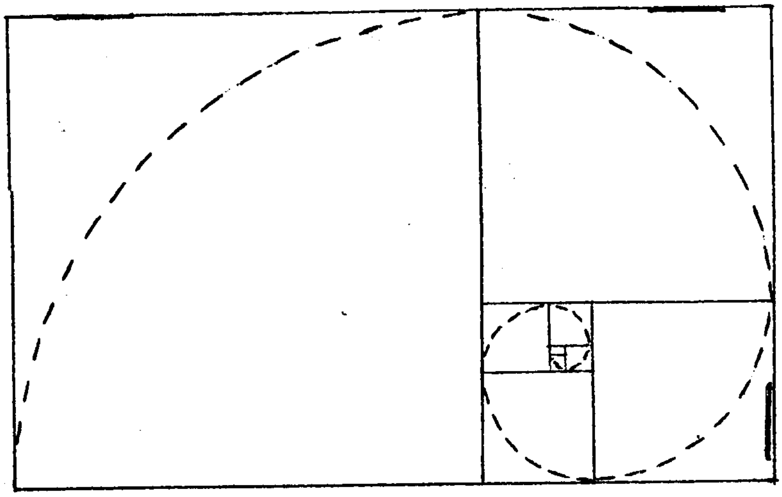


Figure 1.2
Right angled logarithmic spiral derived from Golden Section rectangle.

§1.2 Form of project.

The idea behind this Project was to try and get back to the grass roots of the problem, to attack it with as few preconceived ideas as possible as to what results would be expected and thus not to try to coax all of the results into one theoretical interpretation. An attempt has also been made to obtain results which are statistically significant in a manner which most studies hitherto could not have been, due to their designs.

Before considering the experiments themselves however it is best to consider the previous work produced on this subject, to try and analyse how the methods have failed, and to find the assumptions that have been made in their analyses.

The history of the aesthetics of rectangles is intertwined with the history of the Golden Section itself, and it cannot be considered in its true perspective without some reference to it.

§2.1 History of the Golden Section.

The mathematical discovery of the Golden Section rectangle has variously been ascribed to both Euclid and to Pythagoras. There is however some tentative evidence that the concept was used in the building of the Great Pyramid [9]. The rectangle was definitely referred to and indeed its properties analysed in detail by Euclid in his 'Elements' [14]. Both Euclid and Pythagoras ascribed mathematical (and thus implicitly assumed aesthetic) beauty to the rectangle. The subsequent history of the rectangle until the Middle Ages is far from clear. However it has been found in the notebooks of Vuillard de Honnecourts, which date from around 1235 [26]. Reference is also made to it in the fact that the discoverer of the Fibonacci series (one Leonardo da Pisa, called Fibonacci) observed, around the end of the twelth century, that the limiting value of his series was the golden Number . This discovery must have furthered the beliefs of those who considered that the rectangle was of divine and natural beauty. In 1450 Alberti [1] published his 'Ten Books on Architecture', in which the properties of the Golden Section played a large part. In the half century following this both Durer and Leonardo published works on the subject of the beauty of the figure, and Leonardo attempted to correlate it with the shape of the Human body itself. In 1509 Paccioli published an influential treatise, 'De Divine Proportione' [39]

Little more was heard for about two centuries; then, in 1757, Burke [6] published a volume in which he denied quite categorically that 'beauty has anything to do with calculation and geometry', since proportion is only 'the matter of relative quantities and indifferent to the mind'. In 1855 however Adolf Zeising [54] published a passionate argument for the Golden Section asserting that it was 'central to all order, both in microcosm and macrocosm' and that it was the 'perfect order between absolute unity and absolute variety'. This writing was supported by the experimental findings of Fechner [16], which were published in 1876 (to be descibed in detail later).

From this moment in time the Golden Section would appear to have followed two virtually independent paths, one through Experimental Psychology and the other through Theoretical Aesthetics and the problems of Art and Architecture, although each had a distinct influence upon the other.

§2.2 The Golden Section and Architecture and Theoretical Aesthetics.

From the middle of the nineteenth century to the present day many books, papers, etc., have been published upon the importance of the Golden Section to aesthetics. Of those manifestos which claimed the Golden Section rectangle as an important 'leitmotiv' the following are examples :- Pfeifer,1885 [41]; Henzlmann,1860 [25]; Ghyka,1931 [18]; Lund,1921 [32]; Moessel,1926 [35]; and Funck-Hellet,1951 [17]. Probably the most important contributions to the idea of the theoretical importance of the Golden Section were the publications of Hambridge [23,24] between 1902 and 1926 upon dynamic symmetry. Hambridge studied many buildings, works of art, etc., produced by the Ancient Greeks and found them to be absolutely saturated with the golden section. By including also the work of Church [8] upon the growth of plants he developed the concept of a dynamic symmetry which was intrinsic to nature and was exemplified par execellence in the Golden Section. The influence of Hambridge upon architects was enormous; this influence was both upon contemporary architects such as Teague [47] and also upon later architects such as Le Corbusier [10] who incorporated Hambridges ideas of the Golden Section into his Modulor system, the details of which were first published in English in 1958.

The influence of the idea of the Golden Section is shown in its effect upon the artworld. An example of this is the formation of a group of artists in Paris in 1912, the 'Section d'Or' [54]. This group included such artists as

Leger, Marcel Duchamp, Duchamp-Villon, and Gris. In 1925 Paul Klee in his 'Pedagogical Sketchbook'[30] made reference to the Golden Section, the implication being that it was special in some respect. The later works of Piet Mondriaan are also commonly accepted as being saturated with Golden Section rectangles

The 'staying power' of the concept of the Golden Section is shown by the fact that even in 1958 Borissalevitch [4] could still state categorically that:

> 'It represents the balance between two unequal assymetrical parts, which means that the dominant is neither too big nor too small, so that this ratio appears at once clear, and of just measure. The perception of such a ratio is easy and rapid because of this clarity........ and because it agrees with the hedonistic and aesthetic law, the law of least effort
> hence the beauty of the golden section'.

§2.3 Psychological work upon the Golden Section and related topics.

The first, and probably the most influential, writings upon this topic were those of Fechner in 1876 [16]. Since Fechner's were the first and the most often quoted experiments upon this topic it is as well to look at his method and results in detail.

Fechner seated his subjects in front of a wall on which there were placed rectangles of equal area but of different shapes; these rectangles had the ratios 1.0, 1.205, 1.25, 1.33, 1.44, 1.49, 1.61, 1.75, 2.0, and 2.5. (Log.ratios are respectively 0.0, 0.09, 0.12, 0.15, 0.17, 0.20, 0.24, and 0.40). The subjects looked at the rectangles and then Fechner asked then which one they liked most and then which one they liked least. This was all each individual subject had to do. The number of subjects used by Fechner is not clear although it would appear to be in the region of 300. The results which he obtained are illustrated in Figure 2.1 Fechner considered that these results absolutely supported his case for a population preference for the Golden Mean.

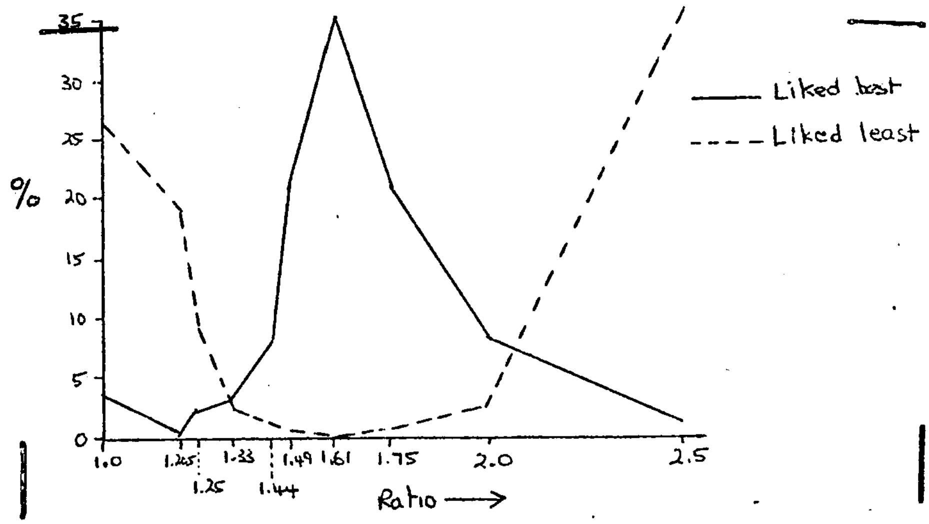


Figure 2,1
Results of Fechner(1876) [16].

In a further attempt to support his theory he also looked at a large number of paintings in art galleries and measured the ratios of the two sides: he found that for 'portrait' type pictures the modal value was at about 0,80 (log,ratio = -0,097), whilst for 'landscape' type pictures the modal value was at around 1,33. It is not clear whether Fechner gave any explanation for this phenomenon, but it has been little publicised in comparison with his other results,

In 1894 Witmer [53] repeated the experiments of Fechner and apparently got similar results; he also published the results which Fechner had obtained with ellipses of differing ratio of minor axis:major axis, The results of this work on ellipses are that subjects didn't like the ellipse with the axes in the ratio of the Golden Section but rather one in which the ellipse was slightly fatter than theory would predict.

Angier(1903) [2] published a study upon a related topic to the Golden Section i.e. the position of division of a straight line for the most pleasing effect. Fechner would no doubt have expected that this position would have been such that a Golden Ratio would have been formed, but Angier's results do not support this prediction.

Haines and Davies(1904) [22] carried out an experiment in which subjects were asked to indicate a preference for rectangles presented one at a time, by either accepting them or rejecting them. They concluded that the Golden Mean phenomenon does not occur on a population basis but that it does apply to many subjects,

Lalo(1908) [31] repeated Fechner's experiments directly and obtained a results curve which may be found in Figure 2.2 The results show important differences from Fechners in two respects; the overall significance of the results is very much reduced, and a substantial proportion of the subjects liked rectangles which had very high ratios: the latter is an important finding with respect to the the present experiments.

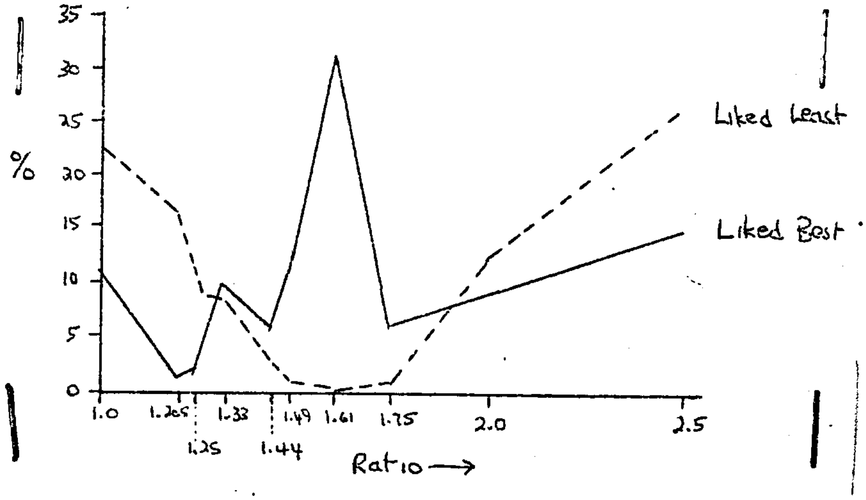


Figure 2.2
Results of Lalo(1908) [31]

Buhler(1913) [5] a Gestalt psychologist , was trying to determine whether rectangles were perceived as a whole or whether they were perceived as a sum of their component parts. He asked subjects to say whether two rectangles of different areas were of the same proportions or different; he found that the accuracy of determination was at least as good as that in judging whether two lines were the same length or different. This is important since it suggests that it is relevant to ask a subject which of two rectangles he finds more preferable, since he is seeing the items as a whole and not as a set of components.

Thorndike(1917) [50] published results on the preferences of subjects for many different geometric forms including rectangles; his results however are of little use since he published none of the data in any detail, indeed he didn't even state what the sizes or the ratios of the rectangles were.

Weber(1931) [51] , a psychoanalyst, attempted to fit the preference of rectangles into a theory of affection. He showed subjects pairs of rectangles and asked them which of the two they preferred (this study was unusual in that all the rectangles were presented only in the vertical orientation). He showed the subjects the rectangles upon two occasions, one a fortnight after the other. The conclusions he draws from his data are that the overall group preferences change with time and that on the second occasion the group were picking longer, thinner rectangles than upon the first occasion. His explanation is that 'practise in seeing rectangles induces a demand for more daring ratios'. However his statistical technique consisted merely of finding the mean of each of the groups and comparing these; if however, as I have done, an Analysis of Variance is carried out upon his results then there is in fact no significant difference between the responses on the two occasions. This supports my own finding that individual preference functions change little over a period of a few weeks.

Davis(1933) [12] adopted a different approach to the problem by asking subjects to draw upon a square sheet of paper the rectangle which they found most pleasing. 45 minutes after asking them to do this he asked them to repeat it and he compared the results upon the two occasions. Taking results as a whole he found modal values of ratios at 1.75, 2.00, and 2.25(log.ratios respectively, 0.243, 0.301, and 0.352). Only 3 per cent of the rectangles were in the range 1.55 to 1.64. On analysis of the results of each subject on the two occasions he found that 31 per cent of the rectangle pairs were within 0.1 of each other, whilst however 20 per cent differed by from 1.0 to 3.1 . Davis concludes that the population is variable in its consistency of responding; this would not however appear to be a justified conclusion considering the nature of the experiment. It is not clear whether he made it clear to the subjects that they neither had to respond the same on both occasions or differently on both occasions, and thus some may have been confused on this point. Also he makes no allowance for the very feasible possibility that subjects may have two rectangle preferences and that it is this which is reflected in the results he obtains.

Ogden(1937) [38] in his presidential address to the American Psychological Association claimed that examination of all great works of art showed that the principal parts of the picture were always found to lie upon certain important points such as the intersection of two Golden Rectangles or else the points of a pentagular star. His claims are not particularly convincing however since, as Valentine(1962) [51] points out, if one draws enough simple geometric figures within a picture then all of the principal points will lie on or near these figures. Valentine also points out that the interpretation of 'principal' point is open, and he claims that in the pictures in Ogden's paper he can find many points which he considers to be of importance but do not lie upon the pentagons, or the other geometrical figures.

Thompson(1946) [48] attempted to analyse the development of rectangle preferences in children. He used four groups of subjects, three being children and the fourth being a group of college students who acted as an adult control group. He found in his adult group (mean age,19.5;S.D. 1.58) that the preference range was from 1.53 to 1.81 (Log.ratios 0.184 to 0.257), thus conforming to previous expectations. The youngest group he used was pre-school children (mean age 3.7, S.D. 0.5); when analysed as a group these children showed no consistent preferences and Thompson concluded that these children had no preferences at all. However in his paper he describes how the children would spend many minutes carefully looking at the pictures before coming to any conclusion; this must surely suggest that they did indeed have preferences as individuals but that when the group was considered as a whole then these preferences averaged out to give Thompson's result. He thus appears to be subject to the logical error of assuming that because the group as a whole showed no consistent preferences then indeed there could be no preferences on an individual basis. He found that his group of children designated as 'third grade' (mean age 8.6, S.D. 0.72) showed some slight preference as a group, but that this preference was weak and centred around a ratio of about 1.33 (log.ratio = 0.123). His sixth graders, (mean age 11.5, S.D. 0.93) showed similar preferences to the third graders in that they centred around a ratio of 1.33, but they were very much stronger preferences which they showed. Thompson, by mathematical methods which he does not enlarge upon, produces a score which he claims is indicative of the degree of preference of the children, this he plots against their age, and thus claims a linear development of preference with age. His results must be considered however to be of little value since he seems not to have even considered the possibility of individuals developing in different ways, and all through the paper there is the implicit assumption that all of the adult population has exactly the same preference functions for rectangles, an unreasonable assumption until it is definitely proven.

Shipley et al.(1947) [45] considered the possibility of a source of error in Thompson's results since in all his studies he used rectangles of constant length, as compared with the more common method of using rectangles of constant area. However Shipley and her colleagues found little difference in the results when either rectangles of constant area or of constant length were used.

Nienstedt and Ross(1951) [37], following in the tradition of Thompson's paper studied the differences in rectangle prefernces in a normal college student group and in a group of old people (mean 78.3, S.D. 6.6). They found distinct preferences in both groups and found that the college student group were similar to those of Thompson's, but that the older group were more like those of Thompson's sixth graders in that they had a preference centred around 0.75. The validity of this result must be disputed since in their study they used only six rectangles of ratios 1.33 to 4.0, and thus to state that the preference is at 1.33 is a doubtful proposition since this is the end of the scale which they are considering, and thus it is quite feasible that these subjects had preferences for rectangles of ratio less than 1.33 but that the structure of the experiment prevented them from expresssing this preference. They also considered the hitherto unconsidered possibility that ones rectangle preferences might alter with the size of the rectangle being observed. They used two series of rectangles, one of area 2.82 sq.ins and the other of area 11.28 sq.ins. They found no difference in the results using these two sizes of rectangles, this however is hardly surprising in the light of the fact that they used rectangles which can only be descibed as being in the class 'small' , i.e. if any differences did exist then it would be expected that it would be much easier to find them by using rectangles which vary widely in size, and thus this result cannot conclusively say that no differences exist, since they may have existed but have been so small as to have not been found in this study.

Stone and Collins(1965) [46] put forward an explanation of the 'accepted preference for the Golden Rectangle' on the basis that perimetric measurements of the visual field show it to be basically rectangular. They fitted the two best rectangles to a field which they had drawn(one inside and the other outside the field) and then took the 'average' of these two fields. This they claim to have a ratio of 1.504, which they consider to be conveniently close to 1.618..., and they thus put forward the theory that the preferred rectangle is that which fills the visual field most exactly. This theory was also put foward by Morris(1962) [36] although Stone and Collins make no reference to this. The theory suffers from several objections. Firstly it is by no means clear that every single person has a preference for this one ratio, and indeed even Fechner's evidence suggests that there are some persons who do not have this preference. Secondly in most of the experiments carried out the stimuli used have been very small and can in no way be considered to fill the visual field. Thirdly it is difficult to conceive that Stone and Collins even considered this theory very seriously since the only evidence they quote in favour of the theory is that 'of ten visiting cards selected at random from the wallet of one of the authors, the average proportions were of the order of 1.6': this is hardly conclusive evidence in favour of their theory. They also terminate with the sentence,'we noticed that a great number of devices which serve to limit the visual field have height-width or width-height ratios similar to that of the golden', Section However this is surely evidence against the golden Section since although from a perimetric hypothesis one would expect ratios of 1.618, there is no obvious reason, without some extension of the theory why a ratio of 0.618 should occur, since the visual field is not at all this shape. (Indeed this was the method used by Schiffman(1966) to try and confirm the theory).

Schiffman(1966) [44] attempted to verify the theory of Stone and Collins by asking 36 subjects to each draw a rectangle, upon a square sheet of paper, as they thought looked best. 35 of the rectangles produced were found to be horizontal in orientation whilst only 1 was vertical. This must be considered as evidence for the theory since it would not predict that vertical rectangles would be preferred at all. However Schiffman points out that the mean value of the ratios of the rectangles drawn was 1.90, and he states that this is not at all what one would expect from the theory; however he is probably unjustified in making this conclusion since in the data he quotes the mean ratio as 0.525 and the standard deviation as 0.104, (he used the opposite convention to this one in respect of orientation, but in this particular case it is meaningless to transform these results since the S.D. will become meaningless) and thus there is probably no significant difference between his results and an 'expected' mean of 0.618 .

§2.4 Summary of position to date of theories of rectangle preferences, and of the Golden Section in particular.

An analysis of the work thus far seems to show certain important features. From the time of Euclid until just before Fechner's work the whole subject was shrouded with mystery and metaphysical significance. A search was always in evidence for some shape which had a reason for being preferred to all others in an absolute rather than a relative sense, as if it had been pre-ordained by some deity.

This however was the position for most fields of human knowledge before science started to analyse them, witness alchemy and the pre-Gallilean concept of astronomy. What is significantly different about this particular field though is that the scientist who decided to carry out an experimental analysis was himself a confirmed metaphysician and mystic, continually in search of a proof of the existence of a force outside of the human mind, and whose intention was to disconfirm all of the contemporary theories of science by so doing[49] .

It is thus not surprising that Fechner should have found a relationship of the form he descibes, since it is exactly the form of data which would be most useful to his ideas. It is not necessary to suggest that Fechner distorted his data in any nefarious manner, but rather that his interpretation was very narrow minded and that he failed to see in his data many facts which would not fit a universal theory of the Golden Mean e.g. that 35% of his subjects preferred rectangles which were outside the range 1.49 to 1.75.

Given Fechner's scientific reputation however it is not unexpected that psychologists tended to accept his ideas virtually wholeheartedly. That this is so is shown by the implicit assumptions shown in most papers on the subject. It is virtually always accepted that there will be only one preference for a subject, and that the preferences for different subjects will be broadly similar across the whole population. As evidence for this consider the number of experiments which looked at the preference functions of individual subjects rather than of groups of subjects; it is virtually zero. In several experiments at least subjects are analysed at two different times and any difference between the two results is interpreted as inconsistency on the part of the subject; the logical alternative of the subject possessing two preferences is never considered.

In no experiment at all has the experimenter looked at preferences for both horizontal and vertical rectangles, but rather again the implicit assumption is present that the results will be the same under both conditions, a completely unjustified assumption with no experimental evidence in its favour.

Considering the general acceptance of the concept of the Golden Mean in scientific circles, it is easy to understand how aestheticians and architects can write theoretical essays on the subject of rectangle preferences and proportion since the whole theory has been given the seal of approval of an 'objective' science. The science indeed appears to be so sure of itself about the basic facts that it feels it can start looking at the phenomenon in terms of its development and its eventual fate in old age [37,45,48].

What then is the status of the Golden Mean hypothesis as even a gross predictor of behaviour in subjects? What reason is there for accepting this particular rectangle or ratio as being of particular importance.

Certainly Fechner's work gives some credence to the idea of the Golden Section being particularly attractive, but the discrepancies in his own data from the expected curve, and more particularly the variability found when his experiments are repeated suggest that perhaps this theory does not provide the full answer.

What evidence is there in fact that this particular ratio is of special importance. It was stated earlier that Hambridge and also Zeiting had found Greek art and architecture to be absolutely saturated with the Golden Section; however this is not necessarily evidence in favour of the hypothesis since others have also looked at the same objects and found that they may be explained on the basis of either a system of proportion based upon commensurable ratios [40], triangulation [13], ratios of small whole numbers [42], or of 'Greek Modules' [34]. Thus this line of evidence is not particularly convincing. Similarly the fact that both Euclid and Pythagoras wrote about this particular rectangle as of having aesthetic significance does not mean that in fact they only considered this rectangle to have significance, and indeed they found many other examples similar to this.

What then is the status of a theory of proportion?. The answer to this must surely be that beyond all statistical doubt a phenomenon of some form exists; subjects do not respond at random when placed in a situation in which they may choose between two rectangles as to which is the most attractive. However there is little reason to suppose that they respond identically or even in a similar manner. There is however good reason to suppose that individuals do have a certain consistency in their response tendencies [52], but there is certainly no a priori reason why the golden section should be involved at all.

Thus a phenomenon exists which is probably more complex than has previously been thought, and which surely deserves an explanation of some sort in psychological terms.

§3.1 Experimental Design

An experimental study of aesthetics requires an experimental design which shows certain features; these are:-

i. The ability to eliminate all extraneous factors such as a tendency to always respond to objects on the right rather than the left i.e. biases of any sort which are no interest to the particular experiment.
ii. The ability to produce results for any one subject which are statistically significant in their own right and may be considered independently from a population analysis, although the ability to perform a population analysis must also be present.
iii. The ability to enable subjects to show preferences over a range instead of a simple two-choice situation which is unlikely to reflect the richness of responses actually available.
iv. The ability to make the entire testing process as automated as possible in order to eliminate subconscious biases of any sort due to the presence of an experimenter, either due to errors in the data recording process itself or else due to the subject trying to produce results which appear to produce a favourable response on the part of the experimenter. The process should also be as fast as possible in order to prevent the subject becoming tired or bored; however the speed of the subject must be a function of the wishes of the subject rather than the experimenter so that the experiment does not become simply a measure of the speed of reaction of the subject.

§3.2 Experimental situation

In order to provide the facilities of §3.1 the following experimental procedure was devised:-

Subjects were sat in front of a ground-glass back-projection screen in front of which was placed a computer console. Projected upon the screen were two rectangles of different ratios. The area of the rectangles was constant in order to remove any effects due to total luminous flux (e.g. a subject might, from the results of Humphrey[28], be expected to prefer the brighter of two stimuli). The subject's view of the experimental situation is shown in Figure 3.1.

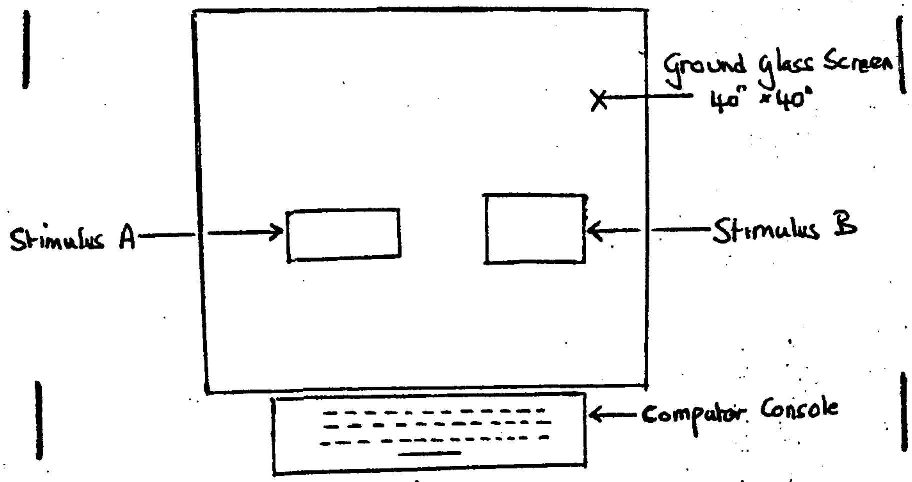


Figure 3.1
Subjects view of the experimental situation.

The computer console was connected for off-line use and was arranged such that it would produce both a printed output and also a paper-tape output suitable for direct input to a computer at a later date. The subject responded to the stimuli by pressing upon one of six of the console keys which were specially marked with metallic blue tape so that they culd easily be seen in the dark by means of the light reflected off of them. These six keys represented different degrees of preference for either of the two stimuli in the manner shown in Figure 3.2 . The subject was carefully instructed that upon each presentation of a pair of stimuli he must press one and only one of the six keys.

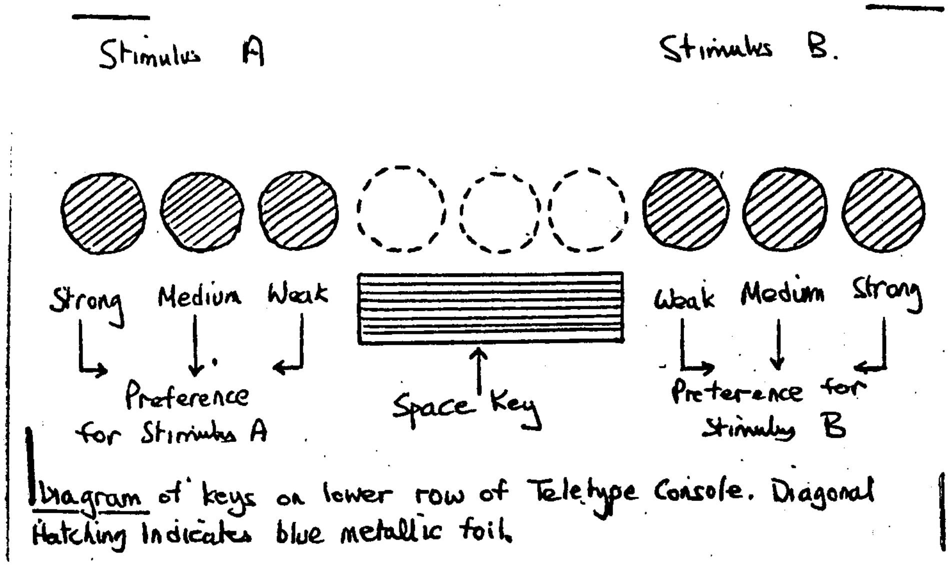


Figure 3.2
Arrangement of response buttons.

The pairs of stimuli were presented automatically by means of an electronic timer coupled to two automatic slide projectors such that up to 45 pairs of slides could be presented one after another. The time of presentation of the slides was variable from about 1 second to about one minute. Subjects were allowed to pick their own rate of presentation; the average time was about 7 seconds and the range was from 4 seconds to 15 seconds.

The stimuli consisted of 2 x 2 slides made from Ilford Ortholith film, which has the desirable property of producing negatives containing only black or white with no intermediate shades of grey. Rectangles cut out of black card were laid upon a sheet of white cardboard and photographed. The negatives thus produced were mounted in cardboard slide frames and used as the stimuli.

15 different ratios of rectangles were used and 14 of each ratio were produced thus giving a total of 210 slides i.e. 105 pairs of slides. Details of the ratios used may be found in Figure 3.3 . These were presented to the subject as 2 batches of 30 slides followed by one batch of 45 slides. Each slide (except of course the squares) could produce either of two ratios by rotating it through 90 degrees, as indicated in Figure 3.3

Figure 3.3
Details of stimuli.

STIMULUS NUMBER	RATIO		LOG.RATIO	
	Horizontal	Vertical	Horizontal	Vertical
S1	1.00	1.00	0.00	0.00
S2	1.072	0.932	0.03	-0.03
S3	1.148	0.871	0.06	-0.06
S4	1.230	0.813	0.09	-0.09
S5	1.318	0.757	0.12	-0.12
S6	1.413	0.709	0.15	-0.15
S7	1.514	0.662	0.18	-0.18
S8	1.622	0.617	0.21	-0.21
S9	1.738	0.574	0.24	-0.24
S10	1.862	0.537	0.27	-0.27
S11	1.995	0.501	0.30	-0.30
S12	2.371	0.422	0.375	-0.375
S13	2.818	0.354	0.45	-0.45
S14	3.350	0.298	0.525	-0.525
S15	3.981	0.251	0.600	-0.600

The order of presentation of the slides was randomised by means of a computer program which produced an order of presentation with the following properties:-

i. The probability of any particular stimulus occurring at any position in the series was equal to all other stimuli occurring in that same position.

ii. Each stimulus occurred once and once only with each other stimulus and never occurred with itself.

iii. The probability of any particular stimulus occurring on either side was equal to it occurring on the other side, with the constraint that each stimulus occurred an equal number of times on each side by the end of the series.

The effect of producing such an order of presentation was that any effects due to a subject tending to respond on one side as opposed to the other for whatever reason be it handedness or some other factor such as slightly different intensities in the two projector bulbs, was balanced out over the course of the experiment.

A plan view of the apparatus is shown in Figure 3.4:-

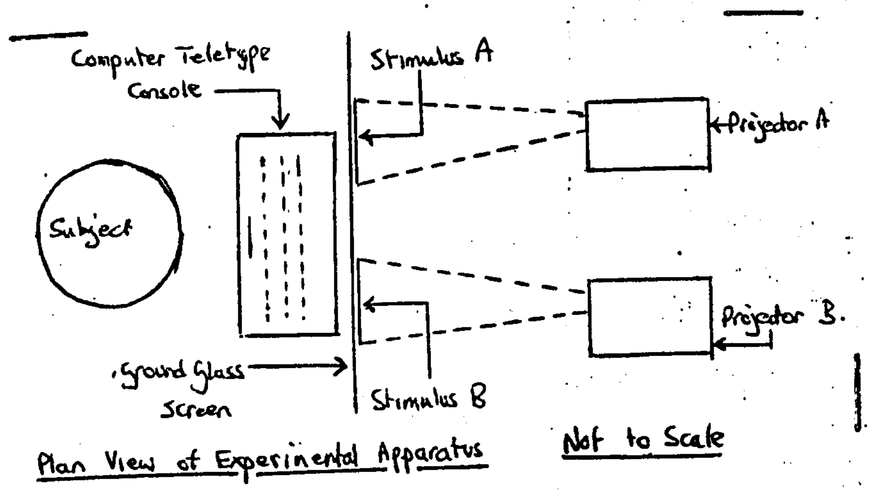


Figure 3.4
plan view of apparatus

For some of the experiments the apparatus was rearranged such that the stimuli were projected upon two 40 x 40 inch projection screens in a normal manner (i.e. by front projection) at a distance of 12' from the subject. The apparatus was arranged such that the visual angle subtended by the stimuli in the two instances (front and back projection) was the same but that the absolute linear dimensions were increased by a factor of 4 in the front projection case. The flux per unit area of the stimuli was kept constant in both cases by means of filters placed over the projectors in the front projection situation. The areas of the stimuli in the back projection situation was 400 square inches and in the back projection case was 25 square inches.

All data was analysed by inputting the punched paper tape direct to the University computer (prototype Atlas Mk II) from the remote console. A program written in ASA FORTRAN produced the results matrices and a graph and table of results which were typed on the console within about 2 minutes of entering the data. The advantage of such a method was that it eliminated experimenter errors in transcribing the data collected (approximately 6000 individual 6 point rating choices).

§3.3 Experimental protocol

The experiment was divided into four stages.

In stage 1 subjects were sat down at a distance of about 3 to 4 feet from a buff coloured wall upon which were stuck 15 (later 13 due to loss of 2 stimuli by theft) black and white reproductions of architectural etchings. The pictures all had different ratios; all were horizontal and the ratios were identical with those of the rectangles used later in the experiment and described in Figure 3.3. The subject was then given the following instructions:-

'This experiment is intended purely to find out your preferences for pictures, patterns and shapes. There are no right or wrong answers to any of the questions and this is not, directly or indirectly, a test of I.Q., personality or whatever. Any questions? This experiment is divided into three stages; this is stage 1. I would like you to look at these 15(13) pictures for about 1 minute; at the end of that time please tell me which one of them you like the best.'

At the end of 1 minute the subject made his/her choice and that particular picture was then removed from the wall. The subject was then asked to make a further choice and so on until all of the pictures had been chosen.

Stages 2 and 3 of the experiment were essentially the same except that different sets of stimuli were used under the two conditions. The subject was sat in front of the computer console and shown which buttons indicated which particular responses. It was explained to the subject that the speed of presentation of the stimuli was completely under his/her control; it was also pointed out that the order of presentation of the stimuli was completely random and that they were not supposed to be looking for any order in the presentation of the slides. In order to allow the subjects to become used to the action of the console and also the different response categories a trial run with about 20 pairs of slides was given; these slides were randomly selected from the main sets. The importance of making one response and only one response to each pair of slides was emphasised to the subject again.

The subject then received the 105 pairs of slides as described above in batches of 30, 30 and then 45.

Different subjects did not all receive the same sets of stimuli and some subjects have also been tested again on this part of the experiment. The details of the subjects and the stimuli given may be found in Figure 3.5 .

Figure 3.5
Details of stimuli given to subjects

SUBJECT	SEX	H@3'	H@12'	V@3'	M@3'	P@3'
1	M	+	+			
2	M	+	+			
3	M	+	+			
4	M	+	+			
5	F	+	+	+		+
6	F	+	+	+	+	
7	M	+	+			
8	F	+	+			
9	F	+*	+	+		
10 Random	M	+	+			
11	F	+	+	+	+	
12	F	+		+		+
13	F	+		+		
14	F	+		+		
16	M	+		+		
17	F	+		+		
18 Random	M	+		+		
19	F	+		+		
20	F	+		+		
21	F	+		+		
22	M	+		+		
23	M	+	+			
24	F	+		+		

KEY: H = Horizontal rectangles
V = Vertical rectangles
M = Series of mixed horizontal and vertical rectangles
P = Subject had patch over one eye
* = Subject tested twice upon this stimulus set
3',12' = Distance of projection

All subjects were tested individuallly for stage 1 and mostly for stages 2 and 3 although a few subjects on stages 2 and 3 were tested in pairs. The average time taken to test each subject was of the order of one and a half to two hours.

§4.1 Analysis of Results

The subject had seen, for a particular set of stimuli, every possible combination of the 15 stimuli. Initially therefore it is convenient to express the results in the form of a 15 x 15 matrix in which each cell represents the preference for one stimulus with respect to one other. The six possible degrees of preference are rated as integers from 0 to 5. An example of such a matrix is shown in Figure 4.1 :-

Figure 4.1
Results matrix for
subject 5.
stimuli horizontal
rectangles at 3'.

Stimuli

	S1														S15	R6	R2
S1	0	2	1	0	1	0	1	0	0	1	0	0	2	1	2	11	0
	3	0	1	2	1	0	1	0	0	0	0	1	1	2	2	14	1
	4	4	0	2	2	1	0	0	0	0	0	1	2	1	3	20	3
	5	3	3	0	2	2	1	1	1	0	1	2	2	2	4	29	4
	4	4	3	3	0	2	1	1	1	1	1	3	1	2	3	30	6
	5	5	4	3	3	0	2	1	1	1	1	1	2	2	3	34	6
Stimuli	4	4	5	4	4	3	0	1	1	0	1	1	2	3	2	35	7
	5	5	5	4	4	4	4	0	1	0	1	1	1	1	5	41	8
	5	5	5	4	4	4	4	4	0	3	2	3	4	4	3	54	13
	4	5	5	5	4	4	5	5	2	0	1	4	5	4	5	58	12
	5	5	5	4	4	4	4	4	3	4	0	0	0	4	4	50	12
	5	4	4	3	2	4	4	4	2	1	5	0	3	5	5	51	11
	3	4	3	3	4	3	3	4	1	0	5	2	0	4	4	43	11
	4	3	4	3	3	3	2	4	1	1	1	0	1	0	5	35	8
S15	3	3	2	1	2	2	3	0	2	0	1	0	1	0	0	20	3

An entry of 5 in the cell represents a strong preference for the ordinate stimulus as compared with the abscissa stimulus, whilst 0 represents the opposite result, and 1 to 4 intermediate results.

The cells on the diagonal which represents the comparison of an object with itself are technically completely empty but for the sake of computational ease they are filled with zeros. A property of such a matrix is that the portion below the diagonal will be an inverted mirror image of the part above the diagonal e.g. cell 10,4 contains 0 and cell 4,10 contains 5.

Although such matrices are invaluable in that they contain a complete record of all the subjects responses they are fairly inconvenient to analyse by eye, and for this reason therefore the matrix so produced is collapsed horizontally into one dimension thus producing a single score for each stimulus which represents the relative degree of preference for that stimulus as compared with the other stimuli in that set. Thus, if for example the subject were using only the extreme preference buttons, and had preferred the square (S_1) to all other stimuli then his score for S_1 would be 14 x 5 =70; however if the converse had applied and the subject had preferred all other rectangles to the square then the score for that stimulus would be 0. Thus 15 preference scores are obtained each in the range 0 to 70. If these scores are plotted against the log.ratio of the rectangles to which they apply then a preference curve directly analogous to that obtained by Fechner, except that it is for an individual as compared with Fechners population study, may be obtained. An example of such a curve is shown in Figure 4.2 :-

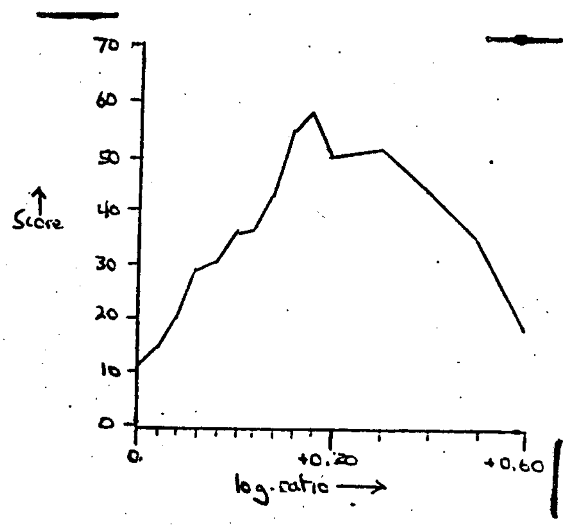
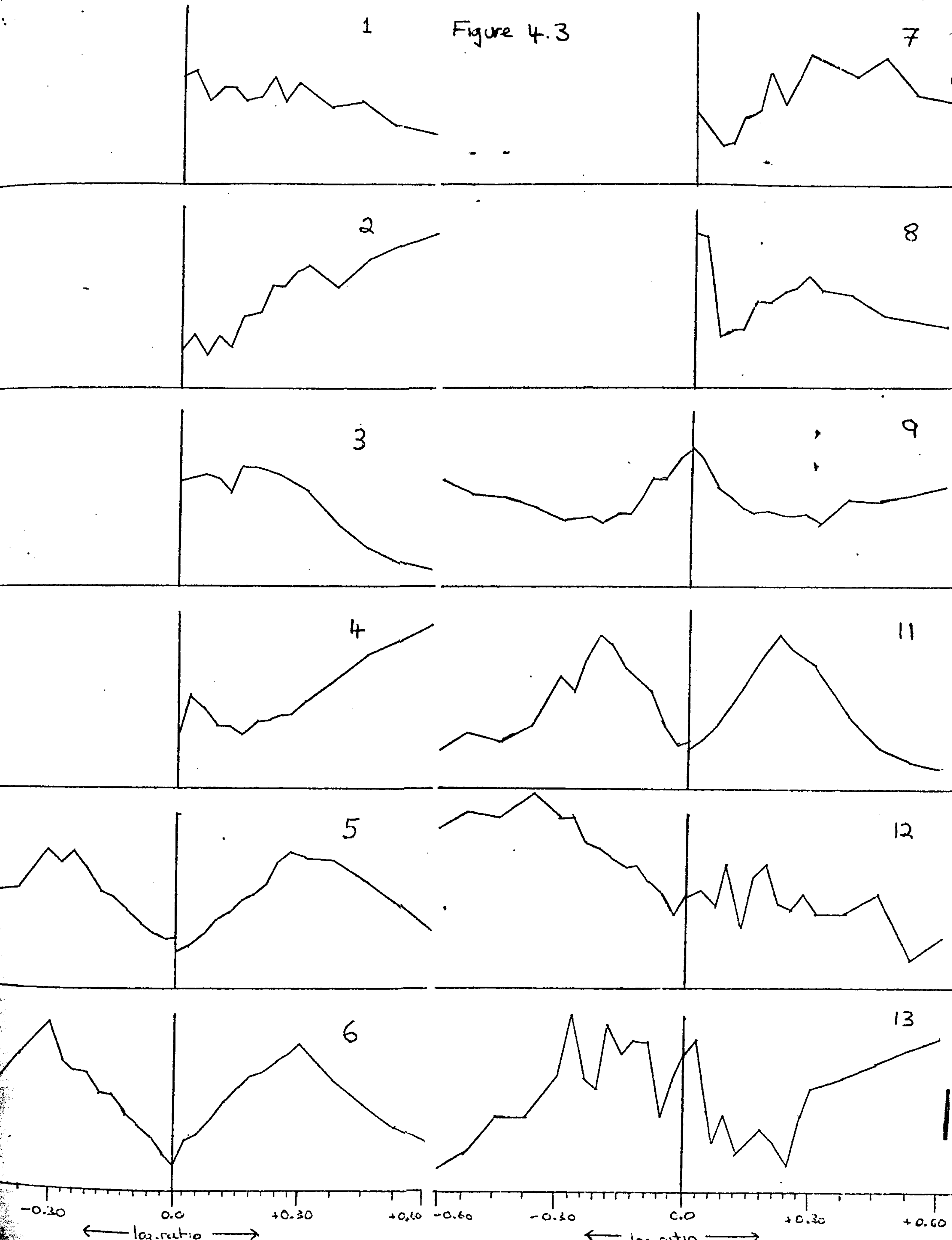


Figure 4.2
Preference curve for subject 5.
Same data as in Figure 4.1

In two separate experiments it is possible to obtain two separate preference curves for a single subject, one for vertical rectangles and one for horizontal rectangles. Both of these curves contain a score for a rectangle of ratio 1.0. Since the scores in the preference curves are only relative to one another it was felt that it was justified to shift the ordinates on one curve so that the scores for the square on both series was the same; having done this it is possible to place the two curves end to end and thus to obtain a preference curve for the range log.ratio +0.60 to log.ratio -0.60. The validity of such a procedure was confirmed in the cases of subjects 6 and 11 by carrying out this procedure and then giving the subjects a set of stimuli containing both horizontal and vertical rectangles and comparing the shape of the composite curve with that of the single curve; there was no difference between the two curves. The intrinsic advantage of such a method is that the number of pairs of stimuli to be compared by the subjects is reduced by a quite considerable amount; thus scores for 30 rectangle ratios may be obtained from 210 presentations as compared with the 435 which would be necessary if all combinations of the 30 stimuli had been used. The disadvantage is that a statistical analysis of the type described later cannot be carried out across the whole range but only over either of the two halves.

The results of this procedure may be seen in Figure 4.3 and 4.4 for all subjects except 10 and 18, whose results have not been given since they were indistinguishable from random and consisted purely of a straight line parallel with the abscissa. Note that not all subjects weere tested on both horizontal and vertical rectangles and thus only half of the preference curve is present in some cases.

Figure 4.3


1
2
3
4
5
6
7
8
9
11
12
13
-0.30
0.0
+0.30
+0.60
-0.60
-0.30
0.0
+0.30
+0.60
← log.ratio →
← log.ratio →

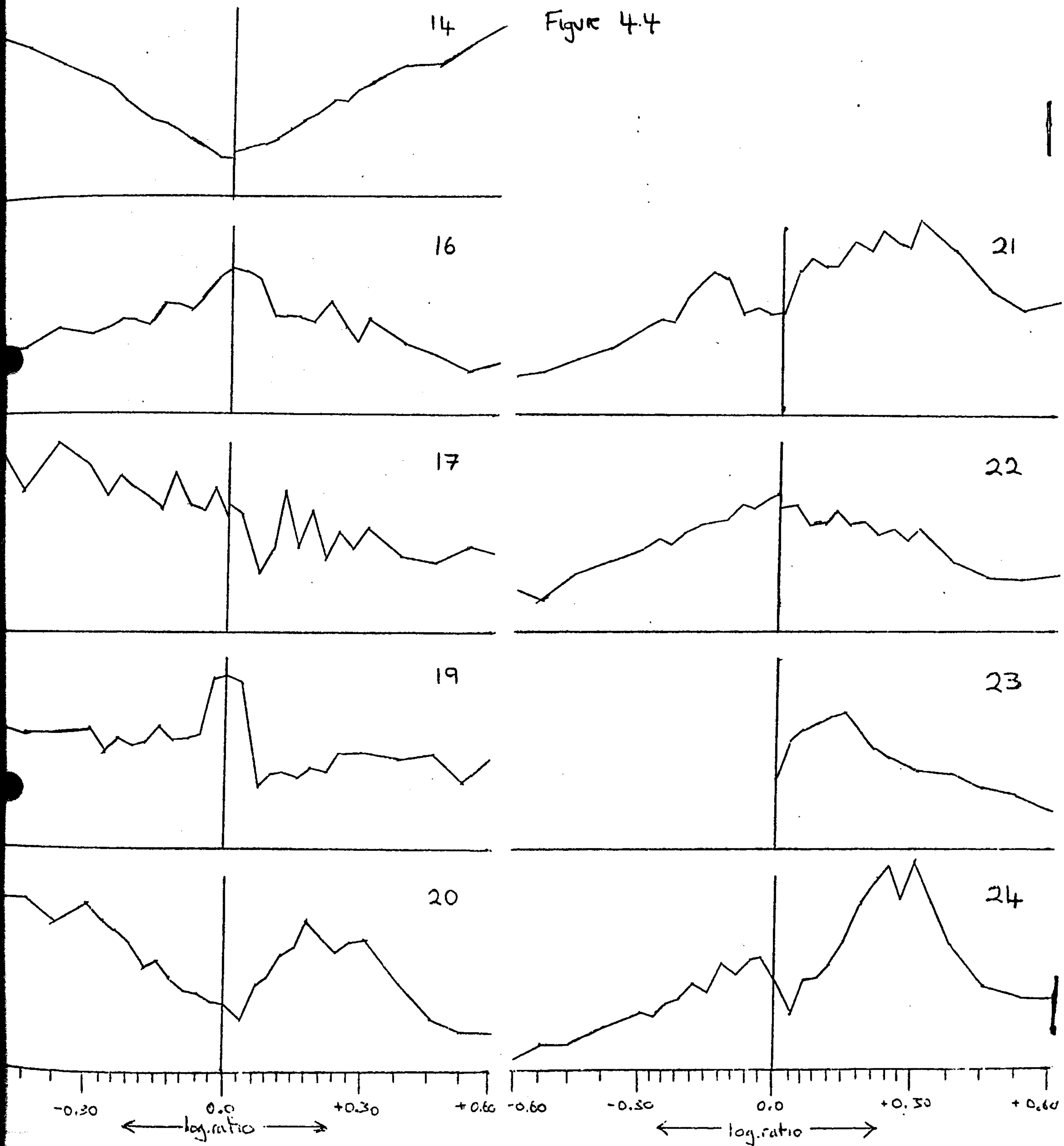


Figure 4.4
14
16
21
17
22
19
23
20
24
-0.30
0.0
+0.30
+0.60
-0.60
-0.30
0.0
+0.30
+0.60
log.ratio
log.ratio

27 4 72

§4.2 Statistical Significance of Results

The first null hypothesis which requires testing is whether the subjects are responding at random or not. There are two possible ways of carrying out this test, one of which is rather more sophisticated than the other, although both have been used.

The easiest test is to have a null hypothesis that on each decisionwhich the subject makes the probability of choosing one stimulus is 0.50. The net result of such a decision rule would be to produce an average preference score for each stimulus of 35, and the degree to which the results differ from this expected result is an indication of the extent to which the null hypothesis may be rejected. In terms of the information statistic therefore one may produce the equation;-

$$I(H_A : H_O) = x_i \log x_i - 105.\log 105 + 105.\log 15$$

where x_i represents the score for Stimulus Si.

The value of 2I will be distributed as a Chi-Squared with 14 degrees of freedom and thus a significance level may readily be obtained.

The second method of analysing the significance is too look at the stimuli in much more detail. Consider three stimuli, a, b, and c. If a→b represents a preference for a over b then there are 8 possible combinations of preferences for a,b, and c. These 8 preferences may be sub- divided into two classes which may be labelled logical and illogical, and these are indicated in Figure 4.5. The distinction between the two classes is that a logical triad shows internal consistency whilst an illogical triad shows no consistency within itself. There are 6 logical triads and 2 illogical triads in the 8 possible combinations.

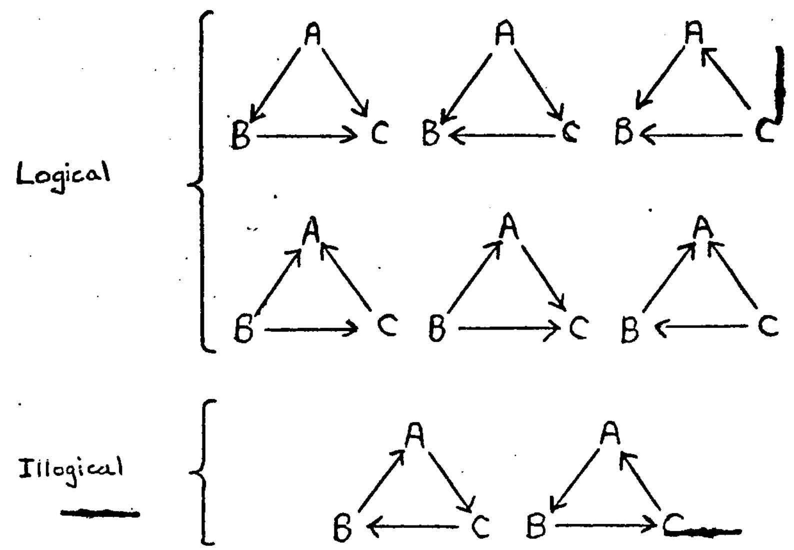


Figure 4.5
Logical and Illogical Triads

Kendall and Babington Smith(1940)[29] have analysed the nature of these illogical triads in some detail, and this has been carried further by David(1969)[11]. In this particular case it can be shown that there are 455 triads in each results matrix. The maximum number of illogical triads which can occur is 140, and in a randomly produced matrix the modal value is at about 120.

It is possible to calculate the numbers of the types of triads from the edge scores of a collapsed matrix but this is only possible if each entry in the matrix is either 0 or 1, i.e. a pure two choice situation must be used rather than a rating scale. In order to do this the results of the matrix are considered in two forms. R6 scores are those already described and an example given of in Figure 4.1. R2 scores are derived from the R6 scores by making a score of 0,1, or 2 equal to 0 and a score of 3, 4, or 5 equal to 1. A binary matrix is thus obtained. If x(i) represents the R2 score of stimulus Si then the number of illogical triads , c, (after Kendall who used the term circular triads) can be shown to be

$$c = (1015 - x(i)^2)/2 \qquad i=1,15$$

The distribution of c in randomly produced matrices is shown in Figure 4.6.

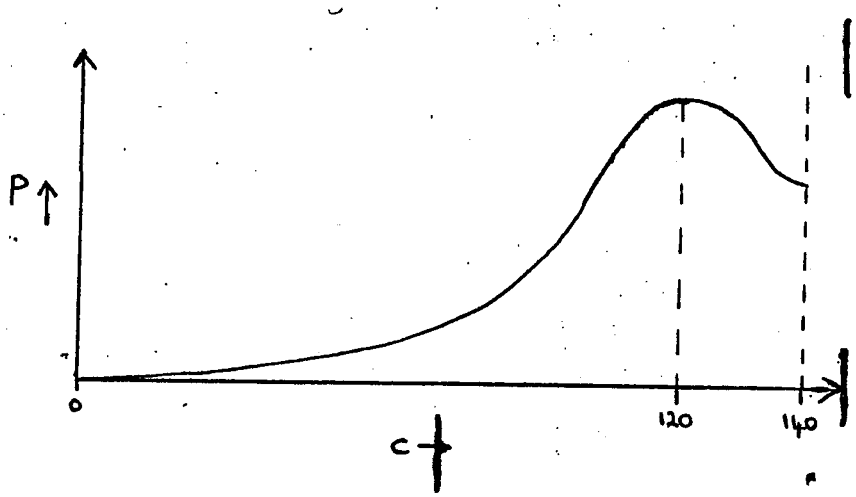


Figure 4.6
Distribution of c in randomly produced matrices.

By suitable transformations (see David(1969)[11]) the level of significance of any score may be obtained in terms of its probability of having been produced by chance. A c score of less than 96 is significant at the 5% level, whilst a score of less than 81 is significant at the 1% level, and a score of less than 72 is significant at the 0.1% level.

This score is obviously a much more sensitive method of measuring the significance of any particular result, the consistency of the subjects responses being of paramount importance to this form of study.

Of the 23 subjects, 2 only (10 and 18) produced results which could not reject the null hypothesis at the 0.05 level on either of the two statistical tests used. 2 subjects had results which were significant at the 0.01 level whilst all the other subjects had at least one result which was significant at the 0.001 level.

By using the rating data it is possible to analyse the data obtained from the triads in a further way. If the subject has an internalised conception of what sorts of rectangles he prefers then it is unlikely that he will produce a large number of illogical triads; however it is reasonable to suppose that when he does do so then the level of significance which he will attach to that result will be much lower than for those which are logical. A prediction therefore is that illogical triads will have weaker levels of responding than will logical triads, this has been confirmed in many of the results and an example is given is Figure 4.7.

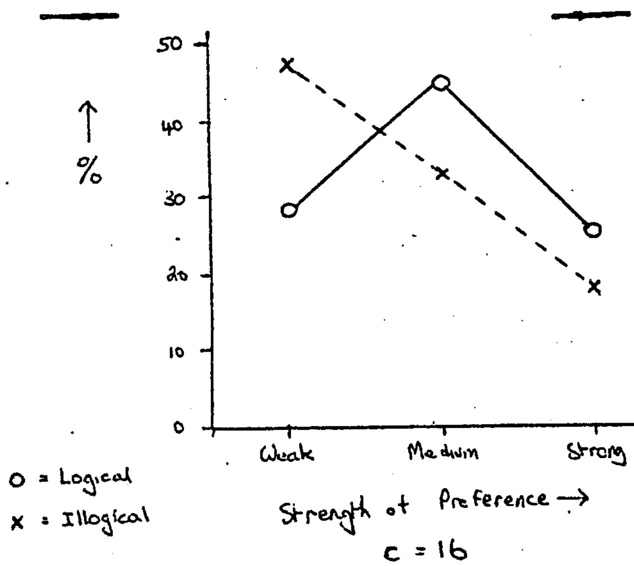


Figure 4.7
Responses in logical and illogical triads. Results of subject 5, data as in Figure 4.1

Thus from these statistical analyses it is clear that subjects do have very strong preferences when presented with a two choice situation between two rectangles and that these preferences are highly consistent within the course of the experiment itself. This is shown graphically in Figure 4.8 which is a plot of c against frequency of occurrence for the results of all the subjects.

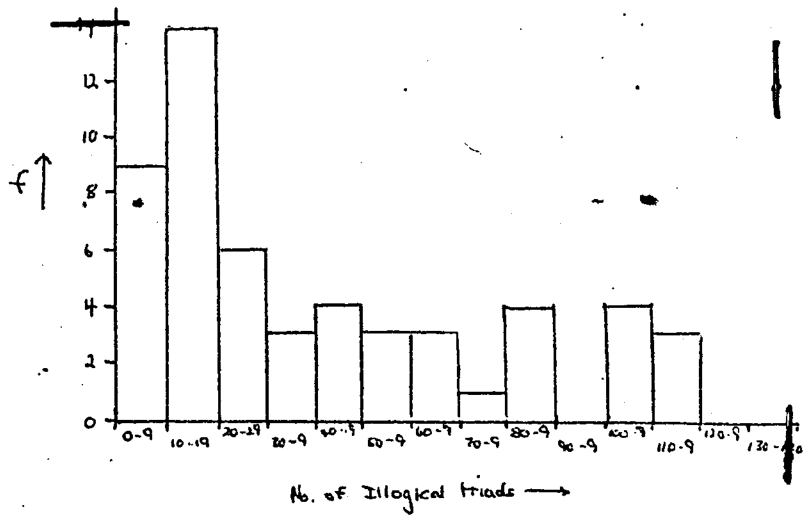


Figure 4.8
Frequency of occurrence of values of c.

It has thus been shown that within one set of stimuli a subject is highly consistent in his responding. The next question which one must consider is how the responses of the subject vary with changes in the conditions of presentation of the stimuli or as a function of time.

In order to analyse this subjects have been given horizontal rectangles under two conditions, according to the distance of projection. In the majority of cases the second set was given after an interval of about 20 minutes from the presentation of the first set. The hypothesis to be tested is that the subjects responses vary with neither size nor an interval of about 20 minutes between successive presentations of similar stimuli.

The results may be analysed by means of Kendall and Babington Smith's [29] Coefficient of agreement, U(+1>U>-1) When two stimulus sets are being compared, +1 indicates complete agreement, -1 indicates complete disagreement, and 0 no relation between the scores. The results of this test upon two sets of data from each subject, one horizontal rectangles at a distance of 3' and the other horizontal rectangles at a distance of 12', with a separation of 20 minutes between the two presentations are given in Figure 4.9

Figure 4.9
Results of coefficient of agreement test as described in text.

SUBJECT	U
1	0.086
2	0.504
3	0.581
4	0.257
5	0.733
6	0.771
7	0.428
8	0.447
9	0.689
10	0.200
11	0.771
23	0.066

It is clear from these results that the responses under the two conditions show little difference and there is a high degree of consistency. In order to test the delay factor a little further 2 subjects were tested after an interval of about 12 days. To find the variation in the responding with other conditions 2 subjects were tested whilst they were wearing a patch over one eye to see if this caused any variation as some theories might predict. The results are shown in Figure 4.10.

Figure 4.10
Results of consistency tests with delays of several days and in cases of wearing a patch over one eye.

SUBJECT	CONDITIONS	U
5	Delay of 12 days, patch over eye on second occasion, horizontal rectangles.	0.723
9	Delay of 11 days, horizontal rectangles	0.846
12	Delay of 20 mins, patch over eye on second occasion, vertical rectangles.	0.697

It can thus be seen that none of the experimental manipulations has substantially altered the pattern of the subjects responding, and one may thus postulate for any subject that the rectangle preference curve will be constant over medium time intervals. This thus confirms the results of Weber(1931)[52] who on re-analysis of his data shows no preference changes with time.

§4.3 Statistical significance of the results of the experimental population as a whole.

Even a cursory glance at the results shown in Figure 4.3 and 4.4 will show that there are very large differences between individuals in their responses to rectangles. Considering the results of Fechner and Lalo it is obviously of great importance to ask whether there is any overall response tendency of subjects across the whole experimental population. A suitable statistical technique for asking such a question is the U score of Kendall and Babington Smith.

If the individual R2 matrices of all the subjects shown the same stimuli are superimposed upon one another then a population response matrix may be obtained. Such a matrix for horizontal rectangles obtained from 2 experiments is shown in Figure 4.11, and for vertical rectangles from 15 experiments in Figure 4.12.

Figure 4.11 Population response matrix for 21 sets of results for horizontal rectangles.

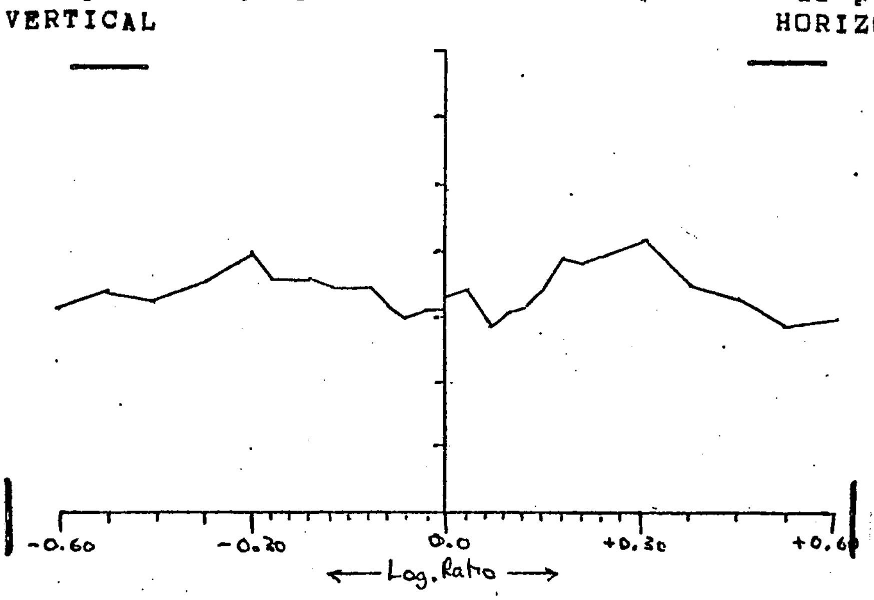
0	12	11	10	5	6	7	11	8	8	9	9	13	13	15	137
9	0	15	10	10	6	9	8	10	9	7	12	13	14	15	147
10	6	0	10	9	7	5	7	6	6	7	11	10	12	12	118
11	11	11	0	12	8	10	6	7	9	8	7	11	12	15	138
16	11	12	9	0	5	10	11	10	7	5	10	13	14	11	144
15	15	14	13	16	0	5	5	11	8	7	16	10	17	13	165
14	12	16	11	11	16	0	14	13	10	10	13	15	15	14	184
10	13	14	15	10	16	7	0	11	10	11	12	14	16	15	174
13	11	15	14	11	10	8	10	0	13	10	13	15	17	16	176
13	12	15	12	14	13	11	11	8	0	13	13	15	17	14	181
12	14	14	13	16	14	11	10	11	8	0	13	16	17	15	184
12	9	10	14	11	5	8	9	8	8	8	0	15	10	15	142
8	8	11	10	8	11	6	7	6	6	5	6	0	12	17	121
8	7	9	9	7	4	6	5	4	4	4	11	9	0	11	98
6	6	9	6	10	8	7	6	5	7	6	6	4	10	0	96

Figure 4.12 Population matrix for 15 sets of results for vertical rectangles.

0	9	8	9	6	5	5	5	7	8	8	7	9	8	9	103
6	0	8	8	5	6	8	7	8	7	6	7	9	7	8	100
7	7	0	5	6	8	6	6	7	7	5	9	6	7	9	95
6	7	10	0	9	4	7	8	5	9	7	7	6	9	8	102
9	10	9	6	0	6	8	10	9	8	4	10	8	8	8	113
10	9	7	11	9	0	4	5	9	7	7	8	8	8	9	111
10	7	9	8	7	11	0	6	6	7	6	7	9	8	9	110
10	8	9	7	5	10	9	0	6	7	6	8	7	9	7	108
8	7	8	10	6	6	9	9	0	8	7	9	8	10	9	114
7	8	8	6	7	8	8	8	7	0	7	6	11	8	9	108
7	9	10	8	11	8	9	9	8	8	0	8	10	8	9	122
8	8	6	8	5	7	8	7	6	9	7	0	9	12	11	111
6	6	9	9	7	7	6	8	7	4	5	6	0	7	10	97
7	8	8	6	7	7	7	6	5	7	7	3	8	0	10	96
6	7	6	7	7	6	6	8	6	6	6	4	5	5	0	85

A response preference curve for the summed R6 scores for both vertical and horizontal rectangles is shown in Figure 4.13.

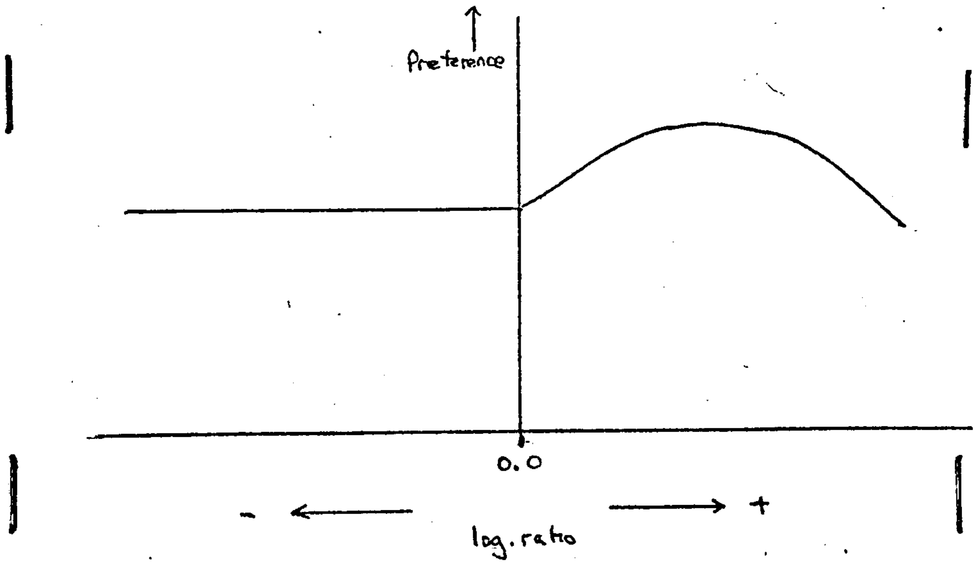
Figure 4.13 Summed preference curves for the experimental population.



The significance of these results can be tested by the method of Kendall and Babington Smith, if n matrices have been superimposed then, if each one is identical, one would expect half the cells in the matrix to contain a score of n and the other half to contain a score of 0. If however the matrices were completely at random with regard to one another then one would expect on average a value of n/2 in each cell (if n is even). The degree to which either of these two conditions is occurring can be tested statistically to produce a value of U, the coeffficient of agreement. The significance of this against the null hypothesis that subjects are responding completely independently of one another may be found.

For the horizontal rectangle matrix the value of U is 0.[redacted] 058 and this is significant at the 0.001 level for rejection of the null hypothesis. (Chi-squared = 257.1, d.f. = [redacted] 132) The vertical rectangles however produce a value of U of -0.023 and this is not significant (Chi-Squared = 90.0, d.f. = 130).

Figure 4.14
Idealised form of population preference function.



§4.4 Relationship of rectangle preferences to picture preferences

It has been fairly clearly shown that subjects have very strong preferences for rectangles. The question to be asked must surely be whether this has any influence upon their liking for very much more complex stimuli such as photographs. In order to answer this question the subjects were, as described earlier, shown pictures of different ratios and asked which they liked best. The results of this were analysed by giving each picture a score between 0 and 70 according to the subjects preference for it. A correlation analysis was then carried out between the preference score for a rectangle of a particular ratio for each subject and the preference score obtained the picture for the same ratio. The result was that for a sample size of 268 picture-rectangle pairs the correlation co-efficient was 0.1216. By using the method of Guilford [20] to test the significance level of a correlation co-efficient it can be shown that such a value would occur by chance only with a probability of 0.03, and therefore this result must be considered as significant. The co-efficient of determination can be calculated to be 0.0147 i.e. about 1.5% of the subjects choice of pictures can be ascribed as due to their shape. That the figure should be so low must be expected and it perhaps helps to put the whole controversy about the Golden Section into its correct perspective.

§4.5 Summary of experimental results.

i. The majority of experimental subjects (21 out of 23) when asked which of two rectangles they preferred responded in a manner which was far from random.

ii. The results obtained from subjects are consistent over variations in size of stimuli, vary little with time intervals of up to 12 days, and are not affected by manipulations of the visual field, as for instance by placing a patch over one eye.

iii. The subjects are able to rank their preferences on a 6 point rating scale in a manner which is consistent with the structure of the logical and illogical triads which can be extracted from their data.

iv. Summation of all the experimental data for horizontal rectangles shows a degree of group consistency which perhaps would not be expected given the large apparent inter-subject variation. Summation of all the data for vertical rectangles shows no such consistency which is statistically significant.

v. There is a positive relationship between the rectangle preferences of a subject and the pictures chosen as being liked best.

'Mystical Idealism'. (After Sachs)

§5.1 Theoretical Analysis.

Theories of the aesthetic preference for rectangles may be broadly divided into two categories:-

a) Theories which state that the golden Section rectangle has a mystical significance and thus an intrinsic beauty. Most versions of this theory do not state what orientation of the rectangle should be used, and indeed suggest that both should be equally effective. If one examines Figure 4.14 then within the limits of the statistics it is not possible to say which rectangle is most preferred, and indeed the Golden Section rectangle would seem to be a good candidate. If this theory were so however one would expect a far greater degree of difference between the different ratios. Further one would expect preference also for a vertical form of the Golden Section rectangle. Examination of the individual function curves in Figure 4.3 and 4.4 will show that only one subject (11) shows a curve which is of the form expected from this theory of rectangle preferences. For these reasons therefore it is necessary to reject any theory purporting to a mystical significance of the Golden Section rectangle.

b) Theories which are based upon the broadly rectangular shape of the visual field, and the idea that the optimal stimulus is that which entirely fills the visual field without overlap. A prediction of this theory is that horizontal rectangles ought to by preferred to vertical rectangles and superficially such a prediction is borne out by the data of figure 4.14. However it is reasonable that such a theory would predict that the nearer a rectangle is to the shape of the visual field then the more likely it is that it would be preferred. Such an assumption would require the preference function for vertical rectangles to have a positive gradient and this does not occur. Further difficulties are encountered for the theory when one examines the individual preference functions in detail. 8 of the functions are distinctly symmetrical about the ordinate and to account for such results in terms of the shape of the visual field requires some degree of conceptual juggling. One would also expect that as the shape of the visual field alters so the preferred shape would change. As the eyes diverge more so the degree of binocular overlap is reduced and the ratio of the visual field increases. No change in preference function occurs if rectangles are shown at three feet distant or twelve feet, even though the degree of divergence is different under the two situations. Using a similar argument one would expect that covering one eye with a patch would alter the response function, but on testing no such change was present.

These difficulties for the theory may be surmounted by using the argument that a particular shape of the visual field is learnt at an earlier stage in life to be satisfying, and that later in life this shape will still have the same effect irrespective of visual field conditions such as divergence or covering of one eye, and also irrespective of orientation in some cases, thus accounting for those curves which are symmetrical. However this form of argument still cannot account for the results shown by subject 12 who has a single preference peak for a vertical rectangle, and for subjects 13,20 and 21 who have two peaks, one for vertical rectangles and one for horizontal rectangles, and the ratios in each case are different. On these grounds therefore it is felt that it is necessary to reject such a theory of rectangle preferences.

It therefore appears that neither of the two hitherto published theories of rectangle preferences are adequate to cope with the empirical data obtained.

A further aesthetic theory which may seem applicable at first is that of the discrepancy hypothesis, due to McClelland and Clark [33]. This proposes that if one is adapted to one particular stimulus, or has a conceptualisation of a dimension in terms of distance from a point on that dimension represented by one particular stimulus, then the degree of aesthetic preference obtained from approximations to the stimulus is related to the similarity of the new stimulus to the adapting stimulus. Thus if it is slightly different then one obtains a more pleasureable sensation, whilst if it is vastly different from the adapting stimulus then one receives no pleasure from it. A theoretical function derived from the theory is shown in Figure 5.1.

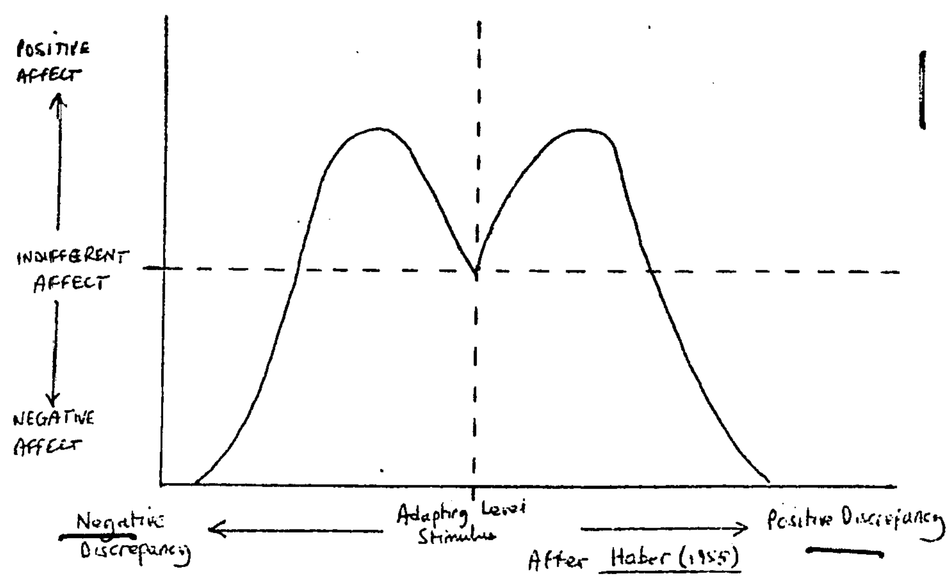


Figure 5.1
Theoretical preference function derived from the discrepancy hypothesis.

Such a theory has much to commend it and indeed it has been shown to be a very satisfactory model for like/dislike with regard to the temperature of water in which the hands are immersed [21]. However the theory suffers from distinct disadvantages when an attempt is made to fit it to rectangle preferences. The curves of subjects, 5, 6,11, and 23 in Figure 4.3 and 4.4 are all remarkably similar to the curve of Figure 5.1. However there are many more individual preference curves which are not remotely similar to Figure 5.1. The reason for this must be that one cannot make an a priori judgment as to which stimulus the subject will take as the adapting level stimulus, and thus from which point he will be discrepant, one can only make post hoc judgments as to the subject's possible categorisations and conceptualisations of the rectangle stimuli. At first sight there are 5 points on the dimension of rectangles which the subject may take as a standard and these are the points with $\log_e$ ratios 0.0, +infinity, -infinity, and two points which represent what might be regarded as an archetypal rectangle, i.e. points such as +0.3 and -0.3. All or none of these may be used by any subject with the addition of many others spaced between these five; this must surely be the fundamental fault in trying to apply the discrepancy hypothesis to rectangle preferences, one has no idea of the position ofthe adapting level stimulus. Even the population results of Figure 4.14 do not show the expected form of the distribution, due to the lack of any significance in the vertical rectangles.

Thus three theories have been invoked to explain rectangle preferences and none of them are at all satisfactory. The abilities necessary for any theory of rectangle preferences are tabled in §5.2.

§5.2 Necessary abilities of a theory of rectangle preferences.

- i. The theory must explain a population preference of the general form shown in Figure 4.14.
- ii. The theory must explain the large variations in individual preference functions, as shown in Figure 4.3 and 4.4, whilst emphasising the small intra-personal variations in results.
- iii. The theory must have the potential of explaining other aesthetic situations of a broadly similar kind.
- iv. It must be capable of experimental verification and prediction to other situations.

In an attempt to satisfy these conditions therefore, a theory of rectangle preferences in particular, and of aesthetic preferences in general has been proposed. At present such a theory can only hope to account for what might be called first-order aesthetics, e.g. simple shapes, colours, etc., due to the absence of knowledge in the field of neurophysiology necessary to take the theory any further.

§5.3 A proposed theory of rectangle preferences in particular and of aesthetics in general.

The visual cortex contains receptors which are sensitive to the orientation of lines in the visual field [27]. The development of these receptive fields is dependent to a very large extent upon the visual environment to which the animal is exposed in its early life [3]. The culture in which we live is essentially rectangular and therefore it is probable that we see many more vertical and horizontal lines than we do sloping lines. Further, due to the effects of perspective and the general verticality of the visual world of the child, we will see many more vertical lines than we will do horizontal lines. Due to this it is not an unreasonable hypothesis that across the entire population the distribution of visual cortex orientation receptors will be of the form shown in Figure 5.2.

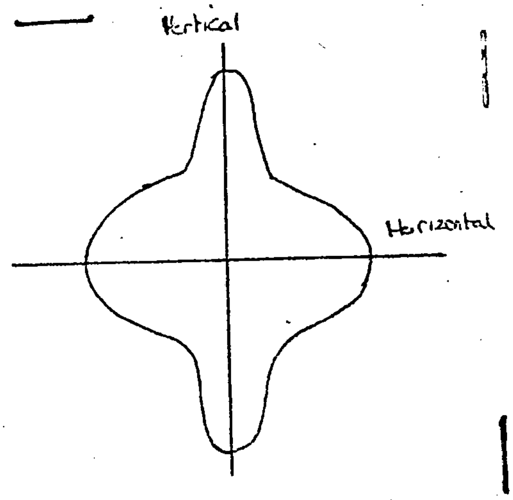


Figure 5.2
Postulated distribution of receptors in visual cortex of man considered as a population, plotted in radial co-ordinates.

The evidence for such a proposition is slight at present; one would expect that if it were so then the visual acuity for gratings with the highest number of receptors present, would be greatest. Campbell and Maffei [7] carried out an acuity experiment and showed that as predicted there was an acuity difference between oblique and vertical or horizontal gratings; however they also found a slight difference between the acuity for vertical and horizontal gratings, the former being the more sensitive. Although they state that this latter result is not statistically significant, it is definitely in the predicted direction, and the lack of significance can be readily ascribed to the very small number of experimental subjects used.

Assuming a distribution of the form shown in Figure 5.2 then it can be shown that a rectangle of the form shown in the experiment when displayed upon such a distribution would produce an output from vertical and horizontal rceptors only. Further, since there are more vertical than horizontal receptors, the output from the vertical cells would be proportionately greater. Consequently the effect of a square would be to produce a greater vertical output than horizontal.

At this point in order to produce an adequate theory one must introduce the concept that all organisms strive continually to maintain a balanced input from all sensory modalities, and also a balanced input within a single sensory modality. On evolutionary terms such a postulate is easily justifiable i.e. it is no good concentrating purely upon vision an ignoring audition since in this state one is liable to be attacked from behind. Similarly it is no good concentrating purely upon the output of one set of receptors in the sense organ (e.g. red cones as opposed to green cones) or one set of analysers at a higher level, but rather one must consider them all since all are liable to be of use in warning, for instance, against approaching predators. Thus the assertion is that an organism has a greatest sense of security and well-being when all of its sensory inputs are balanced.

Thus in evolutionary terms a reason for balancing sensory inputs is apparent. However the principle is possibly also of great importance in the development of the individual. As Blakemore and Cooper [3] have shown, an animal living in a particular visual environment will tend to have receptors only for that environment. This must act as a disadvantage to the organism since its range of analysis of sensory inputs is strictly limited to that which it has experienced before. The balance principle would mean however that an organism would tend to move to an environment for which it has fewer receptors; the action of this in the developing animal would be to increase the likelihood of its inducing these receptors and thus to increase the range of sensory analysis of which it was capable. Such a hypothesis is, in principle, easily testable experimentally. The importance of such a mechanism to an organism is clear. Applying the balance principle to the aesthetics of rectangles it is apparent that the rectangle which will produce a balanced output from the visual cortex is a horizontal one of moderate ratio, and thus the curve in Figure 4.14 may be accounted for.

This theory could therefore explain the population preference curve of Fig 4.14, however it must also explain the individual preference curves of Figures 4.3 and 4.4. These can readily be accounted for by saying that although in general it is expected that the population function for orientation receptors is like Figure 5.2, there is every reason to suppose that such a curve will only occur on summation of the actual distributions of many individuals, and that due to being raised in different visual environments each individual will have a different distribution of receptor orientations.

Even so the theory essentially expects a single peak on the preference curve for each subject and this patently is not the case. However at present one has only considered a single set of receptors of a particular type. We have little idea of the form of the receptors further up in the visual system, although we do know that they very much more complex. It is probable that in requiring a balanced input the system is not looking only at orientation receptors but also receptors at a higher level, which are of a different shape, (possibly rectangular) and of an unknown distribution.

What predictions may be made from such a theory and is it capable of experimental verification? As stated earlier the acuity for a particular orientation of grating is dependent amongst other things upon the number of receptors at each orientation, and thus from Figure 4.3 and 4.4 a few predictions as to the acuity of subjects ought to be possible. E.g. Subject 12 ought to have better horizontal acuity than vertical, and vice-versa for subject 24. Alternatively subject 9 ought to have equal acuity in both orientations.

The theory is also generalisable to one other situation which has been analysed. Humphrey [28] found that monkeys showed a preference for colours in the order blue>green>red. Gross et al. [19] in an analysis of the receptive fields of inferotemporal cortex of monkeys showed that the number of cells sensitive to coloured stimuli only was in the order red>green>blue. The concept of a balanced cortical input readily explains such a result.

If such a theory is to have any credence then it ought to show a degree of predictive power in an untested situation. Consider the stimulus shown in Figure 5.3 :-

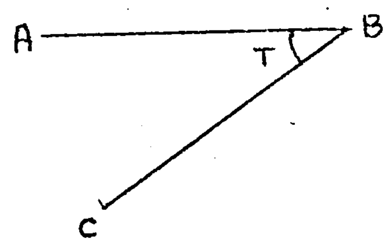


Figure 5.3

The stimulus consists of a horizontal line, AB, and an oblique line, BC, at an angle of T to the horizontal. AB is of the same length as BC. A whole family of stimuli may be constructed by altering the value of T, although it may not equal 0 or 180 degrees.

Since the lengths of AB and BC are constant the output from the orientation detectors will be proportional only to the total number of detectors present at a particular orientation. Invoking the balance principle one finds that if the horizontal and oblique inputs are to be balanced then T must be of the order of 60 to 70 degrees. Further this would be expected if T was either positive (as in Figure 5.3) or negative i.e. BC was above AB.

By utilising the balance principle therefore specific predictions have been made as to the population preference functions in an as yet untested situation. This theory therefore satisfies the requirements of §5.2 fairly adequately.

Accepting this therefore it is as well to consider what the theory does and does not say or imply. This theory is personally envisaged as being one factor (possibly the most primitive) in a complex multifactorial interaction of systems. It does not, and must obviously collapse if one tries to, attempt to explain the entire field of human aesthetics. Thus the importance of factors such as associations with past stimuli, previous history with the object at a personal level, prior history of the object at a social level, contemporary social importance and personal emotional involvement and state at the time of looking at a work of art is not denied. However an attempt is made to plce another more primitive factor alongside these, since the factors thus far invoked appear unable to explain certain of the aesthetic phenomena shown in this report.

considering the theory at its own level, it does not say that the only receptors of importance are the orientation receptors, and indeed for the results of some subjects the presence of others must be implicated. Alternatively it does not say that even for these simple stimuli that the only factors are simple neurophysiological ones, but allows the superimposed possibility of factors such as associations being of importance in some cases.

In conclusion therefore a theory has been presented which can account for certain aesthetic phenomena in neurophysiological and ethological terms. Its assumptions and limitations are clearly stated. Its greatest virtue is that it is theoretically simple but it shows the opportunity of explaining the great complexity which has been shown in the variations between individual subjects. The theory does not intend to be unique amd must be considered as part of a multifactorial system of aesthetics

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