SUBJECTIVE RESPONSES AND EYE FIXATIONS TO VISUAL DISPLAYS OF SPATIAL SEQUENCES

Neville H. Clouten
M. Arch., A.R.A.I.A.

Presented for the Degree Ph.D. in Architecture
The Faculty of Social Sciences

University of Edinburgh

1968

PREFACE

In describing architectural spaces, writers have had recourse to a terminology that is often poetic and uncertain. Zevi suggested that "we adapt ourselves instinctively to the spaces in which we stand, project ourselves into them, fill them ideally with our movements." Arnheim claimed that "movements of air volumes bear out the role of the human beings in the buildings ... hence the channelling and the amplification of our own being that we experience in a successful interior."

Qualitative description encourages an increasing use of words, for there is not the discipline that comes from reducing the complexity of architectural experience to a terminology appropriate for scientific experiment — a terminology that is limited but concise.

The writer has attempted to move from the present state of architectural description to an experiment oriented study. Feasibility studies, some limited more than others by concise objectives, have led to the formulation of a terminology that has then been used in a series of controlled laboratory experiments.

The thesis is divided into six parts.

Part I introduces the architectural basis for the study. The perception and representation of space is discussed in a way that is compatible with the writer's earlier research at the Ohio State University in the application of the principles of photogrammetry to architecture. The recording of eye fixations is seen to be an objective evidence of visual perception. Chapter V reviews past and present methods of eye movement recording.

Part II reports on feasibility studies prepared by the writer to investigate the appropriateness of a standardized stereoscopic photographic method and the validity for questioning subjects on a limited range of possible subjective responses.

In Part III the writer suggests an analysis of spatial sequences that facilitates the photographic recording of architectural spaces for laboratory projection. A review of the methods of personality assessment is given and classifications for subjective scalings are developed. A statement of postulates and hypotheses is given in Chapter XI.

Part IV describes the apparatus and methods used by the writer in experimentation. The results of the experiments are given in Chapter XIV.

Part V presents the statistical analysis of results and isolates relationships that have correlational significance.

Part VI discusses the relationships suggested from this study.

The writer wishes to acknowledge the assistance given by the Department of Architecture, Edinburgh University, in the provision of electronic and photographic equipment. A number of visits to E.M.I. Laboratories in Feltham, Middlesex, have been made during the past two years and thanks are due to Mr. B. Shackel for describing pilot studies in Electro-oculography. In the electronic recording of eye fixations the assistance of Mr. D. Parker, Senior Technician in the Department of Architecture, is acknowledged. Forty subjects have taken part in the experiments described in this study. Their readiness to participate has been very much appreciated.

The writer wishes to thank, most of all, the Supervisors for this research —

Mr. P. F. Crofts, Adviser for Post-graduate studies in the Department of Architecture, whose discussion and criticism of the project in regular meetings has continually given encouragement to the writer.

Dr. B. Semeonoff, Department of Psychology, whose discussion of the experimental and statistical aspects of this study has been of particular value.

N. H. C.

TABLE OF CONTENTS

PART IV. EXPERIMENT

PART V. CORRELATIONS

PART VI. CONCLUSIONS

LIST OF TABLES

Table

Table

LIST OF ILLUSTRATIONS

Figure

Figure

Figure

Figure

INTRODUCTION

I. SPACE

The term Space is used in a variety of ways for different purposes. An architect may consider that space is mathematically generated from orthographic plans and sections. Alternatively, he may insist that man's sequential and subjective experience is an essential part in defining space. Or he may accept that space is unlimited and then seek another term to describe spaces in buildings.

The Gestalt definition of figure and ground has been extrapolated to show that convex forms are seen as figure, concave as ground. Undulating curves may be seen as convex from either side. This is illustrated in the familiar shift in perception from black vase on white ground to two convex faces in profile, Fig. 1.

Gestalt psychology provides a clear analysis for two-dimensional painting and three-dimensional sculpture. In architectural drawings and photographs the convexities of structure are emphasized graphically

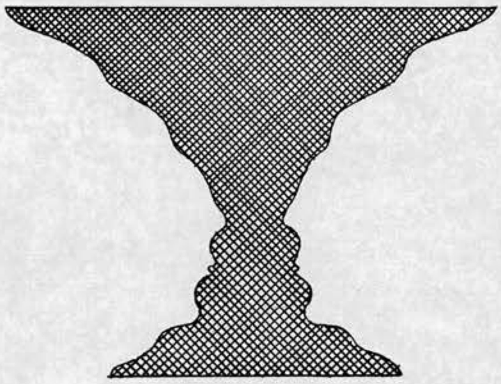


Fig. 1. Convexity.
(From Rasmussen)

and seen as figure. The consideration of the concavity, space, is relegated subordinate. Rasmussen (1959) applied the figure and ground concept to the experience of architectural space.

> "I use the word <u>space</u> to express that which in three dimensions corresponds to 'background' in two dimensions, and <u>cavity</u> for the limited, architecturally formed space."[1]

The term <u>space</u> is subordinate to structure in this context. Structure is then seen as a convexity. But structure is seen as a concavity when linked with <u>cavity</u>. The supplementary terminology is confusing but the conception is important.

---

[1] S. E. Rasmussen, <u>Experiencing Architecture</u> (London: Chapman & Hall, 1959) 48.

A "background" space and a "limited, architecturally formed space" describe the concave and convex perception of space. And in the same way that a shift in the perception of convexity in figure and ground may occur in graphics, so in architectural experience a shift may occur in the perception of convexity in structure and space. Ambiguity, in graphics and in architecture, appears in a balancing of convexities.

Arnheim (1966) maintained that space is not always the residual of building minus structure, but can be a convex volume of air with definite meaning.

> "It is only necessary to walk through a traditional church to realize that the walls and ceilings are not simply positive shapes, looked at from empty space, the way we look at a piece of sculpture. They are rather the shell of an air volume that fills the interior and in the midst of which we find ourselves. The internal shape corresponding to the external convexity of a cupola is not so much a concave hollow surface as it is a second internal dome made of air. Instead of two contradictory aspects created by the outer and inner surfaces of the stone construction — one of them convex, the other concave — we perceive two volumes fitted into each other, like the cores in the old flat irons or the foot inside the boot."[2]

The architects of the Baroque period exploited the convexity of space. Structure was then a resultant of

[2] R. Arnheim, W. M. Zucker and J. Watterson, "Inside and Outside in Architecture: A Symposium," Journ. Aesth. & Art Crit., 25:1, (1966) 4.

interior and exterior spatial needs, Fig. 2.

> "The concave facade in the Baroque church accommodates spatial needs that are specifically different on the inside and the outside. The concave exterior, at odds with the church's essential concave spatial function inside, acknowledges a contrasting exterior need for a spatial pause in the street."[3]

The design of urban and architectural space provides paths for physical progression, but then

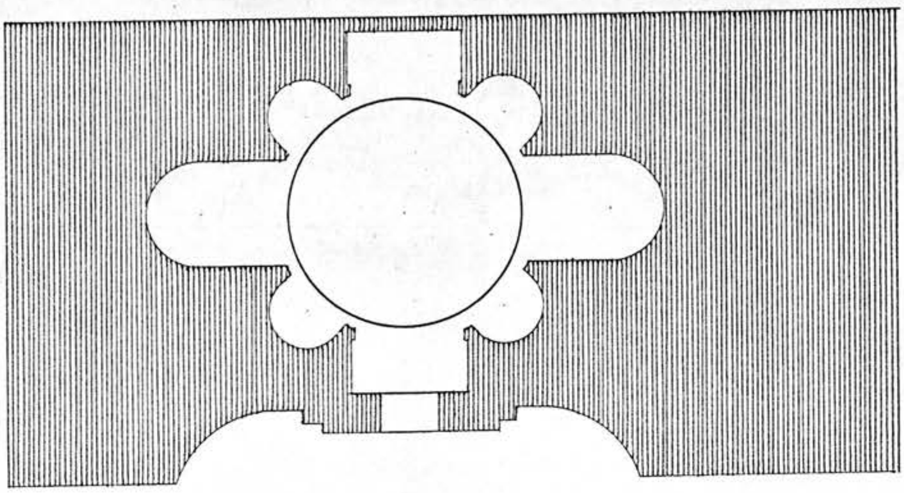


Fig. 2. Convexity of Interior and Exterior Space. Sant Agnese in Piazza Navona, Rome.

---

[3] R. Venturi, Complexity and Contradiction in Architecture (New York: The Museum of Modern Art Papers on Architecture, I, 1966) 86.

exploits these paths to involve the perceptual systems of a subject. Le Corbusier emphasized the sequential and subjective experience of space.

> "Space is the foot that walks, the eye that sees, the head that turns."[4]

Man is not an onlooker in architectural space. His sequential and subjective experience is integral with the reality of the space. Architectural space is then an air volume, on occasions itself seen as a convexity, that has been designed with meaning and formed by precise limitation to fulfil needs of an environment for man. And it is capable of being experienced by a moving subject normally responding to visual, thermal, tactile, acoustic and olfactory stimulation.

---

[4]As quoted, E. Perry, "The Major Space," Prog. Arch., 46:6, (1965) 153.

II. THE PERCEPTION OF SPACE

It is essential to discriminate between the subjective perception of space and the means that may be used to represent this perception. The artist translates the visible scene of depth, distance and solidity to a flat image. The history of Realism in painting is the history of recording techniques that reduce three-dimensional spaces and volumes to two-dimensional images.

> "To limit the ambiguity of perspective, the artist must make use of perceptual distance cues available to the single eye. He is forbidden the binocular cues of convergence and disparity, and also motion parallax. Indeed these cues will work against him. Paintings are generally more compelling in depth when viewed with a single eye, and the head held still."[5]

If there were any indication that cues of shading, perspective and texture were largely responsible for the perception of space, it would follow that static monocular vision would provide major clarification in

---

[5] R. L. Gregory, Eye and Brain: The Psychology of Seeing (London: Weidenfeld & Nicolson, 1966) 169.

this perception. This has been a generally accepted view.

> "The painter exploits these [pictorial cues] to produce the illusion of depth on a canvas without benefit of the parallaxes. It has seemed possible that these cues are recognized early in development as having differential value and so become endowed early with spatial meaning."[6]

Bower (1966) described a test for the isolation of primary cues in the perception of space.

> "Infants in one group wore a patch over one eye so that they could not register binocular parallax but could register only motion parallax and pictorial cues. A second group viewed, instead of the real cubes, projected slides that were rich in pictorial cues but lacked both binocular and motion parallax entirely. A third group of infants wore specially constructed goggles and viewed projected stereograms of the various scenes; their presentation contained binocular parallax and pictorial cues but lacked motion parallax.
>
> "It appeared that motion parallax was the most effective cue to depth, followed by binocular parallax. The static pictorial cues in the retinal image seemed to be of no value."[7]

Binocular disparity in adults provides an immediate impression of distance. A sequence of slightly different perspectives is introduced by motion

---

[6]T. G. R. Bower, "The Visual World of Infants," <u>Sc. Amer., 213:12,</u> (1966) 84.

[7]<u>Ibid.,</u> 87,88.

parallax, near objects being displaced further and faster than more distant objects.

In the Introduction to "The Perception of the Visual World" Gibson (1950) made this statement.

> "The problem is to state without any theoretical prejudgment what we see when we say that we perceive the environment."[8]

Immediately, however, this prejudgment is given to the reader.

> "Look at the room not as a room but, in so far as you can, as if it consisted of areas or patches of coloured surface, divided up by contours. To do so you must fixate your eyes on some prominent point and then pay attention not to that point, as is natural, but to the whole range of what you can see, keeping your eyes still fixed. The attitude you should take is that of the perspective draughtsman. It may help if you close one eye. ... One gets it only by trying to see the visual world in perspective and to see its colours as a painter does."[9]

Pictorial cues for the graphical representation of space are the concern of the artist, art critic and art historian. In general the psychologist has maintained a close link with these professions. A symposium on "Space Perception" (1959) re-emphasized

---

[8] J. J. Gibson, The Perception of the Visual World (Cambridge, Mass: Houghton Mifflin, 1950) 26.
[9] Ibid., 27.

the generally accepted importance of visual cues derived from pictorial depth representation. Vernon, as moderator for the symposium, summarized with the following observation.

> "I cannot help concluding that the laws and principles which have been hypothesized by the speakers in the symposium from the phenomena discussed cannot be extended beyond the narrowly limited field of these phenomena and applied in general to the perception of objects in space. We cannot tell whether the latter type of perception is based upon and develops from the simple types of form and movement perception described in this symposium; or whether it arises in some other fashion and is governed by quite other laws and principles."[10]

It is shown diagrammatically that the size of a retinal image is proportional to viewing distance, Fig. 3. In viewing an object from two positions, however, the object appears to retain its size and shape regardless of variation in viewing distance and orientation. The perception seems faithful to the object rather than to its retinal image. Such relationships are described as spatial constancies.

The first theory of constancy learning, formulated by Helmholtz, suggested that each retinal projection isolated a response of distance and orientation. With experience the retinal projections became familiar and

---

[10] M. D. Vernon, "Space Perception: A Symposium," Acta Psychol., 15, (1959) 268-269.

were then additionally capable of defining size and shape. According to this theory there could be no constancy for an unfamiliar object. A later empiricist theory, developed from Koffka, assumed that a predictable relationship existed between object distance and size, and between orientation and shape. Once the relationship was learned by the child, size and shape were inferred from variation in distance and orientation. Constancies could then apply to familiar and unfamiliar objects.

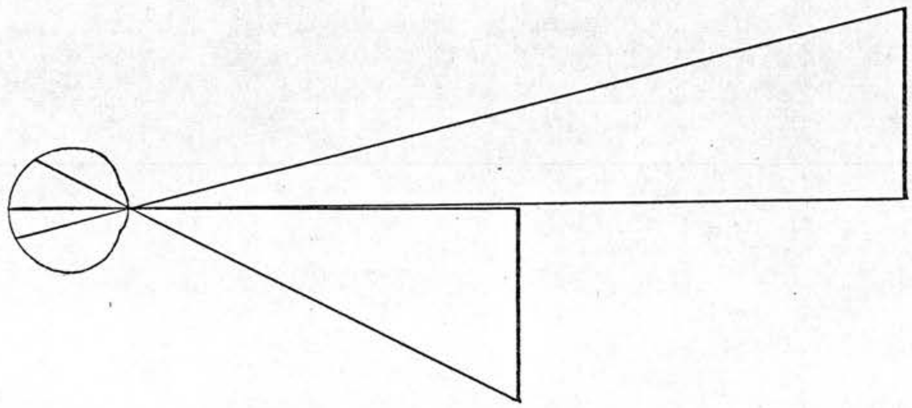


Fig. 3. Retinal Image and Viewing Distance.
(Adapted from Bower)

Cattell (1900) summarized experiments "On Relations of Time and Space in Vision".

> "Visual perceptions are built up by the individual in the course of experience and may differ greatly in different individuals. For the infant the visual world is probably a chaos."[11]

From the several experiments on the perception of infants, Bower (1966) stated these conclusions.

> "The eight-week-old infants certainly were more capable of depth discrimination, orientation discrimination, size constancy, shape constancy and completion than an empiricist would have predicted. On the other hand, the babies were also less capable than a strict nativist would have predicted. They could not discriminate pictorial cues and they could not maintain shape constancy and orientation discrimination simultaneously.
>
> "These results suggest a theory of perceptual and perceptual-motor development. It is obvious that an adult is capable of some responses these infants apparently lacked. For example, the infants in the second shape-constancy experiment seemed to be unable to register shape and orientation simultaneously but able to register orientation in the case of a surface without limiting contours. The most plausible hypothesis is to assume that infants have a lower processing capacity than adults — that their perceptual systems can handle simultaneously only a fraction of the information they register. Infants can register the real shape of an object and they can also register its orientation. If they have limited processing capacity,

---

[11] J. M. Cattell, "On Relations of Time and Space in Vision," Psychol. Review, 7:4, (1900) 343.

however, they may be able to process only one of these variables even though both are present and are registered."[12]

It would seem likely that it is not the perceptual process but the ability to register information that has to be learned.[13]

Rather than directed to the isolated momentary retinal image, the human perceptual system is tuned to receive sequential information — the type of information given by motion parallax and binocular parallax.

A series of experiments on adult subjects by Deyo (1922) assessed the relative importance of binocular parallax and the size of retinal image. Each subject was seated twenty feet from a stationary rod. A movable

---

[12] Bower, Op. cit., 90,92.

[13] Mackworth and Bruner (1965) observed qualitatively that children were less successful than adults in examining pictures. This was also apparent from their quantitative measurement of effective visual search. "One requirement is for the gaze to be narrowly concentrated to process detailed structures in the visual scene; whereas the other requirement calls for exactly the opposite in the sense that the gaze must also explore rather widely throughout the scene. Measurements of both these aspects of performance give clear signs that children are less able to solve this simple dilemma in the display."
The authors conclude that the incidence of short "step" eye movements in children, while they may have been due to visual acuity limitations, are more likely the result of processing limitations in the children.
N. H. Mackworth and J. S. Bruner, Selecting Visual Information during Recognition by Adults and Children (Harvard: Center for Cognitive Studies, 1965) 32.

rod was introduced at varying distances to a maximum of 150mm from the stationary rod. The experiment ascertained, for monocular and binocular vision at the distance, the minimum distance in depth required for depth discrimination. The results are shown in Fig. 4.

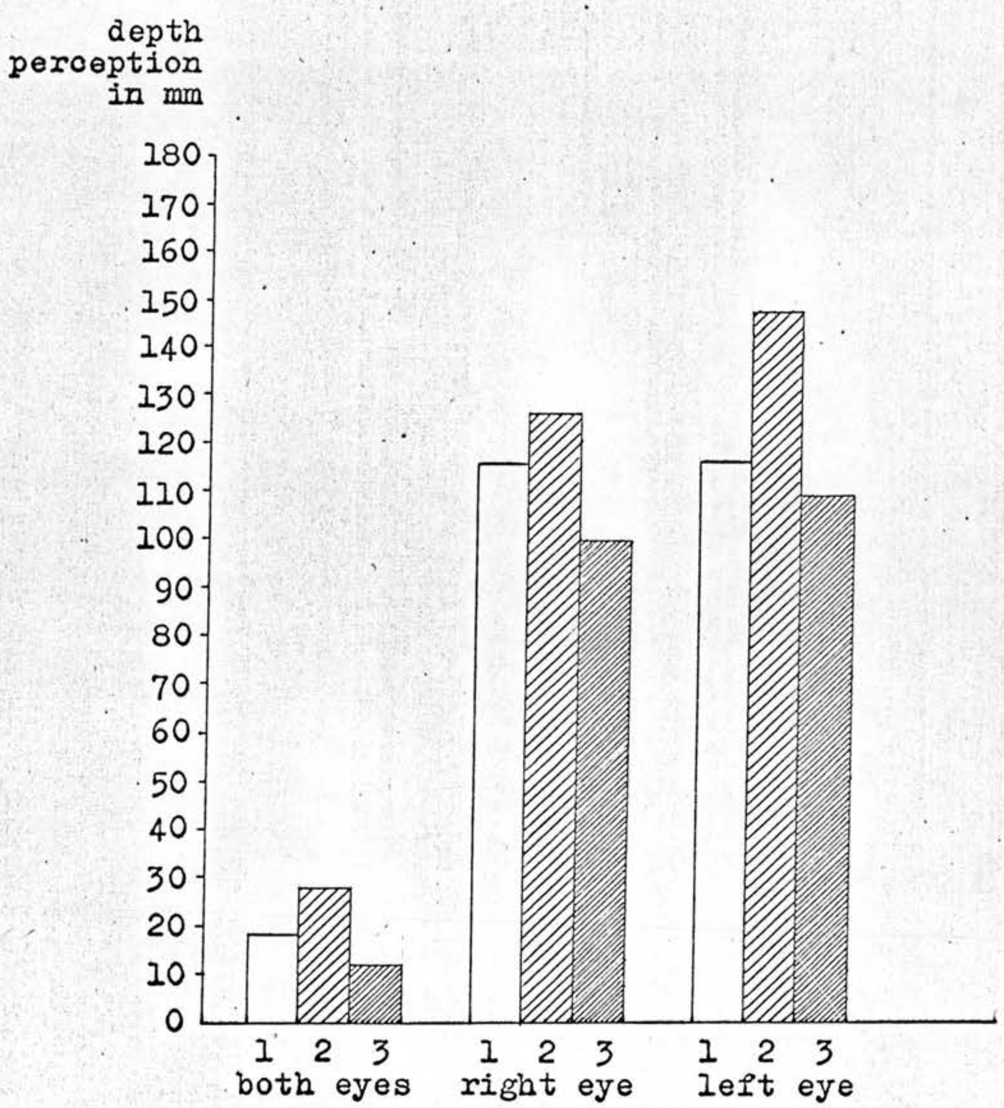
> "The great difference in judgments of depth perception made with binocular and monocular vision would tend to prove that it is the binocular parallax which is the all important factor in depth perception judgment, and that the size of the retinal image which operates in monocular vision is of practically negligible importance in judgment of distance. It is plain that for accurate depth perception judgment good binocular vision is necessary, and the results of these tests show that the better the visual acuity, the more exact the depth perception judgment tends to be."[14]

This quotation raises two points.

Firstly, both motion parallax and binocular parallax have now been referred to as the primary factor in depth perception. Clearly, the basis for each parallax is the same — a base between visual images. In the case of binocular parallax the images are simultaneous, separated by an interocular distance of approximately 2½ inches. Julesz (1960) has shown that specially prepared computer-generated patterns, which appear random under normal viewing conditions, provide

---

[14] B. V. Deyo, "Monocular and Binocular Judgment of Distance," Amer. Journ. Ophthal., 5:3, (1922) 347.



1. Complete group.
2. 20/20 visual acuity group.
3. 20/15 visual acuity group.

Figures on left indicate distance one rod must be in front of the other for recognition.

Fig. 4. Monocular and Binocular Judgment of Distance. (From Deyo).

immediate perception of depth when presented as stereopairs to the left and right eye. There are no visual cues in the computer-generated patterns to supplement binocular vision. In the case of motion parallax, sequential retinal images vary from movement of the eye position. The image from one position is then superimposed on the image from a prior position that has been retained on the retina by eye memory. By exploiting motion parallax in motion picture photography it is possible, with the sequential two-dimensional display, to obtain a similar subjective impression of depth as that obtained by binocular vision from a stationary position.

Secondly, visual acuity[15] has been stated to be a parameter in accurate placement of depth. Beyond this, is there mathematical definition for binocular depth perception judgment?

Hallert (1960) provided the following derivation.

> "If the values of the stereoscopic visual acuity are expressed in angle measurement, it is easy to compute the resulting uncertainty in stereoscopic distance perception. ... A point A is regarded at a distance a and under the

---

[15] Visual acuity is defined by the least angle through which two points may be differentiated as distinct entities. This varies in part according to the density of the light-sensitive cones in the fovea.

converging angle γ. The visual base line (eye distance) is b. Since the triangle is almost isosceles and the angle γ is small, the following relation holds true:

$$\gamma = \frac{b}{a} \text{ radians}$$

"The influence of minute errors in the angle γ at the distance a is derived by differentiation:

$$d\gamma = -\frac{b}{a^2} \cdot da$$

$$da = -\frac{a^2}{b} \cdot d\gamma$$

"This means that an error in the angle γ is related to an error in the distance a proportional to the square of this distance."[16]

The binocular or stereoscopic visual acuity is normally approximately twice that of monocular visual acuity. There is considerable individual variation but discrimination of differences between two points, laterally or in depth, can generally be made for a minimum converging angle between the points within the range 1^c to 30^{cc}.

If the interocular distance b is taken to be 2.5 inches and with $d\gamma$ expressed in radians, errors in

[16]B. Hallert, Photogrammetry (New York: McGraw Hill, 1960) 56, 57.

depth perception can be computed for variation in viewing distance, Table I.

Table I. Errors of Depth Perception.

Distance a	Error of Depth Perception da	
	For $d\gamma = 1^{c}$	For $d\gamma = 30^{cc}$
1 ft.	0.00075 ft.	0.00023 ft.
10	0.075	0.023
100	7.5	2.3
1000	750	226
1250	1250	375
4000		4000

Visual cues of overlay, relative size of objects, effects of light, shade and atmospheric conditions are most effective within the range of binocular uncertainty of depth perception, and beyond the distance at which the benefits of binocular vision cease. From Table I this latter distance has been shown to lie between 1250 ft and 4000 ft. The addition of motion parallax, as experienced in highway travel, increases the effective base b and so increases depth perception.

Kittler (1968) discussed some peculiarities in the perception of architectural space with reference to the work of von Sterneck and Gilinsky.

> "One thing is certain — the farther the buildings are, the nearer they relatively seem to be to the observer in comparison to their real physical distance.
>
> "In reality the size of architectonic space is governed neither by the law of size constancy nor by the law of the retinal image.
>
> "The architectonic space surrounded with tall buildings appears to shrink to smaller dimensions causing ... the impression of being at the bottom of a well, e.g., when standing in a street or square surrounded by skyscrapers."[17]

There is agreement among architects that apparent distance appears shorter than physical distance, and that apparent height is consistently less than physical height. Borchers (1965) summarized this as follows.

> "It appears to be a general rule that our total uncertainty of depth perception may be interpreted as a shortening of apparent distance, accompanied by a relative reduction of all dimensions observed at increasing distances."[18]

The above quotations are illustrated in Fig. 5, 6.

---

[17] R. Kittler, Some Spatial and Environmental Considerations of Architectural Design based on the Perceptual Phenomena of Vision under Daylight Conditions. (Bratislava: Inst. Const. & Arch., Slovak Acad. Sc., 1968) 9, 11, 14.

[18] P. E. Borchers, "Photogrammetrie et Architecture," Bulletin de la Soc. Franc. de Photogram., 19, (1965) 78.

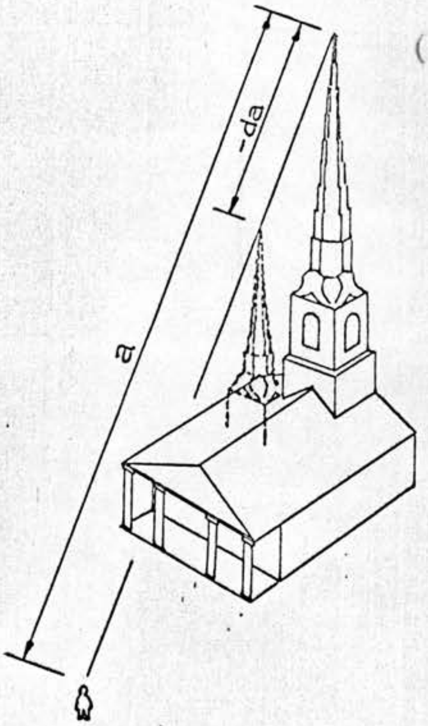


Fig. 5. Error of Stereoscopic Distance Perception. (Adapted from Borchers).

$$a = \sqrt{(200-5.5)^2 + 40^2}$$
$$= 199 \text{ ft.}$$

$$b = 2.5 \text{ inches} = 0.208 \text{ ft.}$$

$$d\gamma = 0.0001 \text{ radians}$$

$$da = -\frac{a^2}{b} \cdot d\gamma$$
$$= 19 \text{ ft.}$$

Coordinates of apparent height:

3.8 ft. in front of physical distance.

18.5 ft. lower than physical height.

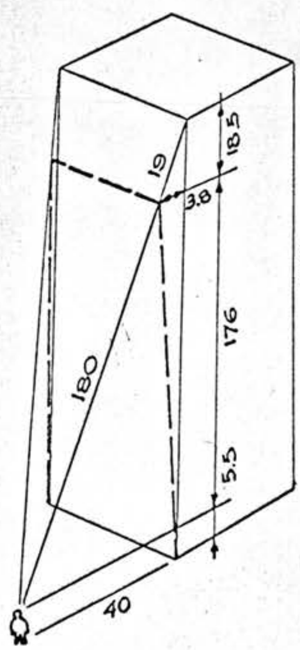


Fig. 6. Calculation of Apparent Height.

Hallert's formula for an increasing error in depth perception is applicable in each case. In Fig. 6 an apparent height is computed for a 200 ft high building viewed by a subject 40 ft from the base. Average visual acuity figures are taken for this calculation.

In "An Eye Movement Study of Stereoscopic Vision" Clark (1936) reported quantitative measurement of eye fixations from stereograms.

> "It is difficult to see how kinaesthetic sensations from the extra-ocular muscles could be of any major importance in stereoscopic perception, in view of the fact that the eye movements were so consistently irregular during fixation of points in and out of context. Therefore, these findings throw into question theories that attempt to explain stereoscopic vision and depth perception on the basis of kinaesthetic cues.
>
> "On the basis of these findings, it can be concluded that stereoscopic vision involves the perception of a series of intermittent, continuously changing retinal impressions received from the stereograms. The oscillations between clear and blurred vision are the result of the tremulous movements of the eyes occuring on the average about 8 times per second. The clear perception occurs during fixation, and between fixations there are periods of lowered acuity of vision.
>
> "Stereoscopic vision is to be explained fundamentally as due to the organization and unification of these inordinate retinal impressions and not simply in terms of the stimulation of specific points on the retina."[19]

---

[19] B. Clark, "An Eye Movement Study of Stereoscopic Vision," Amer. Journ. Psychol., 48, (1936) 91, 94, 96.

Ditchburn (1959) has shown that small involuntary eye movements, which at first would appear to represent an imperfect balance of the three pairs of muscles acting on the eye in different directions, are in fact essential in normal vision. An analysis of eye movement recordings revealed the irregular rapid oscillatory movement or "tremor" in addition to the sharp saccadic "flicks" and slow "drifts".

> "Eye movements of suitable excursus will swing the image pattern across the receptors and, as the edge passes across a given receptor, a strong signal will be generated.
>
> "Cones near the edge may pass into darkness and others previously in darkness may receive illumination as the result of tremor excursus. The tremor is thus capable of firing the on and off action if illumination is sufficiently large. If the tremor were the only movement, then certain nerve fibres would be transmitting strong signals as long as the subject gazed steadily at a given target. These fibres would accommodate and cease to transmit. The drift moves a boundary on to a new set of receptors after about 0.5 seconds. It is advantageous for the drift to proceed in one direction so as to use new receptors continually. If, however, the drift continued in one direction for too long then the point of interest would move out of the central territory. The flicks transfer the image to a new region, usually within the central territory, from which the drift starts again in a new direction. In this way the whole of the central territory is used in an efficient way."[20]

---

[20] R. W. Ditchburn, "Eye Movements and Visual Perception," Research (London), 9, 466, 468.

Ditchburn describes the method used by Fender to stabilize the image on the retina. When 95% of the

A definition of the perception of space would seem to begin with cognitive implications, of necessity mention the predominance of visual stimulation, and additionally include the primary visual factors of binocular parallax and visual acuity given in the mathematical definition of depth perception.

The perception of space results from a selective process of isolating wanted information from environmental noise. Visual, thermal, tactile, acoustic and olfactory stimuli are isolated and together these may establish a sense of space. The most frequent response to a stimulus believed to be significant is an eye movement which attempts to centralize the stimulus on or near the fovea.
In addition to horizontal and vertical eye movements, the visual response includes the differential horizontal movements of binocular vision which, limited by visual acuity, indicate placement of the stimulus in depth.

---

natural movements were compensated there occured a fade out, then after ten seconds an uncontrollable sharp movement. Ditchburn described the experience.
"It is difficult to convey to a person who has never seen it the strange quality of vision in the absence of eye movements. The 'information' reaching the brain from the retina is of a kind never before experienced; The sense of bewilderment is sometimes very unpleasant."

III. THE REPRESENTATION OF SPACE

The establishment and qualification of a sense of space is largely attributed to visual data, but that from acoustic, thermal, tactile and olfactory perception is also present. Acute awareness of data from one factor in perception, or a variety of factors, may lead to a sense of involvement in the space.

In the design of spaces the architect projects himself into a concept of environment and by creative imagination experiences the spaces. The graphical representation of space is here an intermediate tool in the continuous process of conceptual creativity to reality.

In the viewing of reproductions of architectural space the architect relates his assessment to the impressions he carries of an actual visit to those spaces or otherwise, by association, he recalls analogous sequential experiences from examples in actuality or from his conceptions. The viewing of a graphical representation of space remains an abstraction unless made real by associated impressions.

The more common methods of spatial representation available to a designer include orthographic drawing, perspective projection and scale model construction. The plan, elevation and section conveniently define measurement along Cartesian ordinates of space. The perspective drawing illustrates selected orthographic measurements from an isolated point of view. The scale model illustrates relationships between component spaces and structures without reference to the spectator. The architect's ability is again required in order to project man's mass into the model spaces at a true scale. The relationship between the dimensions of the building and the dimensions of man is then reinstated.

If the experience of architectural space consisted of the sum of the width, length and height of the structure enclosing space, orthographic drawings would record the experience of the space directly. But the subjective experience may be far more or less than the physical dimensions infer. In the case of the perspective drawing, the isolated point of view must be multiplied to correspond with sequential experience. Thiel (1961) emphasized that methods of orthographic and perspective drawing were inadequate for recording spatial experience.

> "Neither a series of perspective sketches nor orthographic projections are adequate for the job. The former are most commonly discontinuous, eye-level representations from successive discrete points of view — the latter are fragmented representations of spatial aspects 'seen' from a viewpoint at an infinite distance.
>
> "The discontinuous form of a series of sketches ... and the infinite viewpoint and disconnectedness of orthographic projection ... renders these methods unsuitable for the representation of such a continuous process of transformation as vision in motion."[21]

Thiel then presented a sequence-experience notation of space. Halprin (1965) reported a notation of motion, Fig. 7. In this case there is an indication that the notation has widest application to the design process.

> "Since we have no technique for describing the activity that occurs within space or within buildings, we cannot adequately plan for it."[22]

The sequence-experience notation and Halprin's Motation provide a vocabulary of symbols capable of

---

[21] P. Thiel, "A Sequence-Experience Notation," Town Plan. Review, 32:1, (1961) 34.

[22] L. Halprin, "Motation," Prog. Arch., 46:7, (1965) 126.

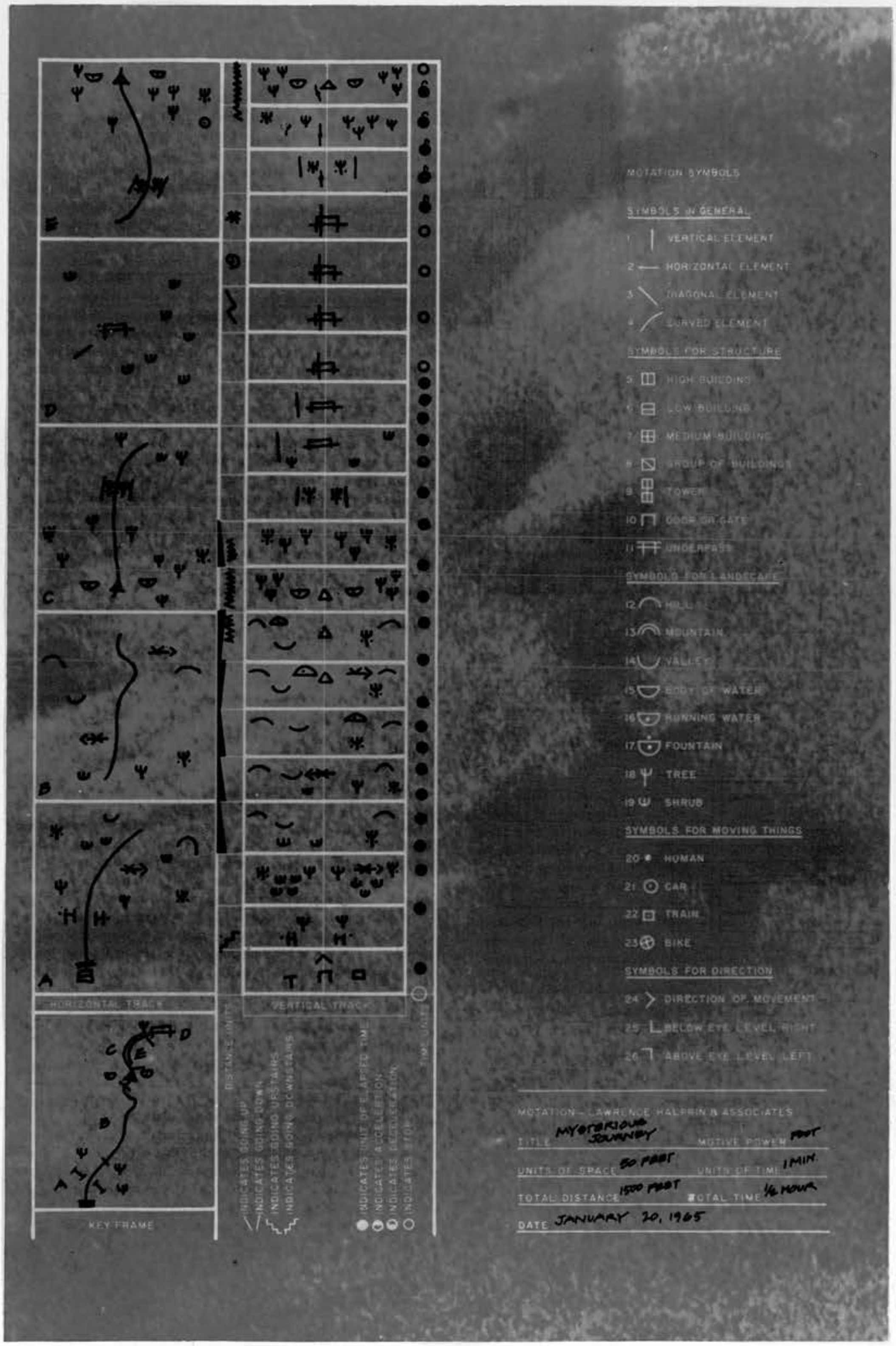


Fig. 7. A Notation of Motion.
(From Halprin)

graphically representing spaces, volumes, surfaces and events experienced in varied combination in a time sequence. The notation may organize the conceptual process; and by its structure it may provide a method of translating to symbols the subjective impressions of any one participant in the experience of several spaces simultaneously or sequentially. But without the individual's associated impressions the notation remains an abstraction. The underlying problem of obtaining an accurate experience from graphical representation cannot be solved simply by the substitution of symbols for precise measurement.

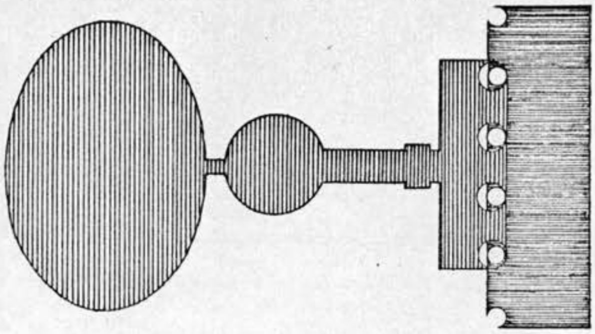
The notation is capable of recording sequential information, the perspective drawing a static point of view. The orthographic projection has no claim to represent space, but is a practical device to record measurements. Zevi (1957) considered it important to add spatial meaning to the orthographic drawing. However, it is likely to be more rewarding to accept the plan, elevation and section for physical definition, then supplement this with qualitative and quantitative methods of spatial analysis, even though these may be fragmentary.

Attempts have been made by the writer to record qualitative spatial experience in graphical figures.

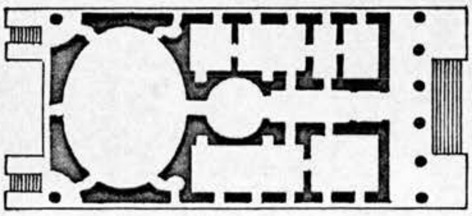
Ten subjects were asked on separate occasions to enter and progress through the spaces in the Montgomery County Court House, Dayton, Ohio. None of the subjects had entered the building prior to the time of the experiment. No briefing was given as to the component spaces or the order in which these spaces were to be experienced.

From questioning each subject as to his initial contact with the spaces in the building, certain resemblances were found to exist. These have been represented in the qualitative diagram, Fig. 8(a). A change from exterior to interior scale is shown to occur at the entrance to the building. The figure may be compared with the plan, Fig. 8(b), and a volume diagram (c). The volume of each component space was obtained by calculation from measurements in plan and section, and drawn so that the form of the two-dimensional plan has been maintained. The scale in each case, however, is reduced or expanded to express cubic measure.

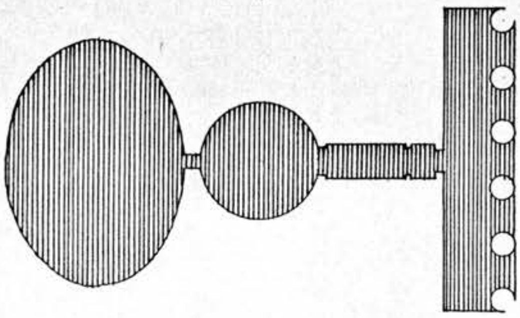
Graphical methods are appropriate for the recording of quantitative measures of thermal and acoustic variation that qualify an individual's position in space. Fig. 9 illustrates temperature recordings in the Montgomery County Court House. In this figure the positions of the original Franklin stoves are shown as



(a) Qualitative Diagram.



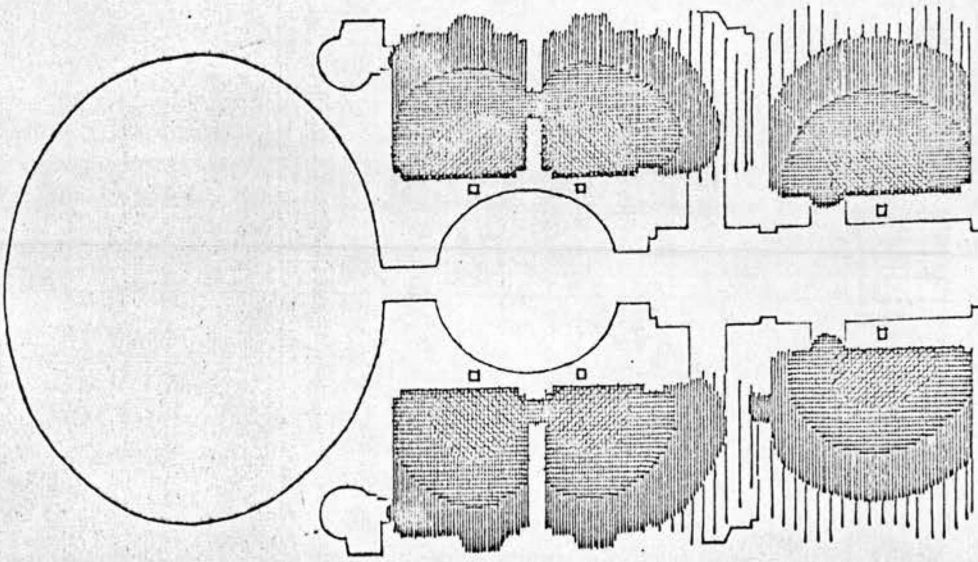
(b) Plan.



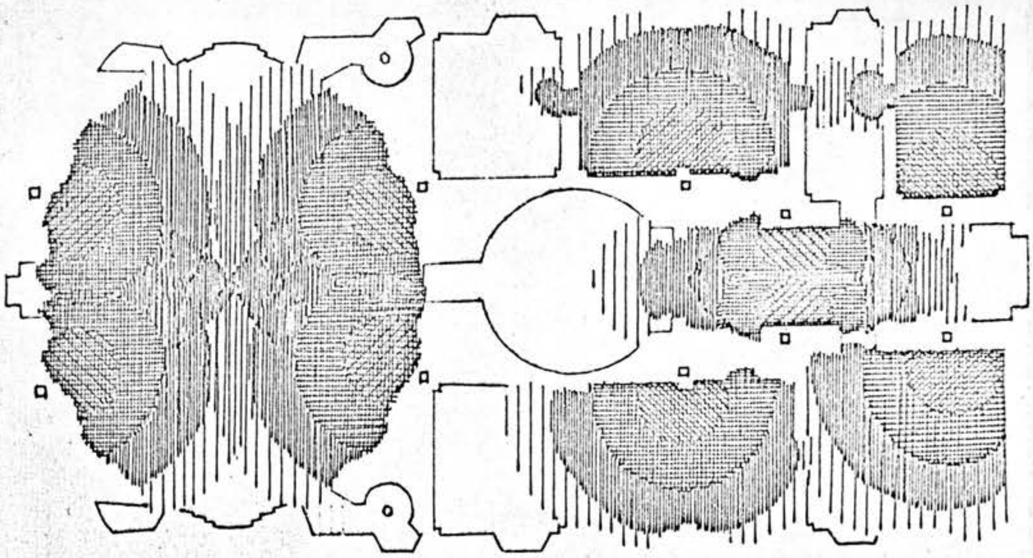
(c) Volume Diagram.

Scale: Each diagram is drawn such that the width of the entrance hall is similar.

Fig. 8. Qualitative Diagram of Subjective Experience Compared with Plan and Volume Diagram. The Montgomery County Court House, Dayton, Ohio.



(a) First Floor Plan.



(b) Ground Floor Plan.

Fig. 9. Thermal Diagram of Temperature Recordings.
The Montgomery County Court House,
Dayton, Ohio.

heat sources. Thermal variation in a space can only be defined by a number of sets of measurements. In addition to measurements of radiant heat these may include variations in surface temperature and air movement. The recording of acoustic and lighting conditions would similarly require measurement of several factors.

A montage of photographic reproductions, each a central projection from a point in space, has been used to illustrate progression through architectural space, Fig. 10.

It is now opportune to proceed beyond the representation of fragmentary factors capable of isolation, to methods that infer or claim to record the totality of visual experience in architectural space.

The scale model provides adequate spatial representation for many purposes. It is essential that the interocular distance is scaled down to the model scale, a condition which is readily achieved by an endoscope.[23] Photography of models requires the selection of an appropriate camera focal length. The

---

[23]"Modelscope" — A hand-held optical instrument with a short focal length lens fitted to a 3/16 inch diameter by 12 inch long repeater-system telescope. "Model Viewing: Special Equipment," <u>Prog. Arch., 46:6,</u> 84.

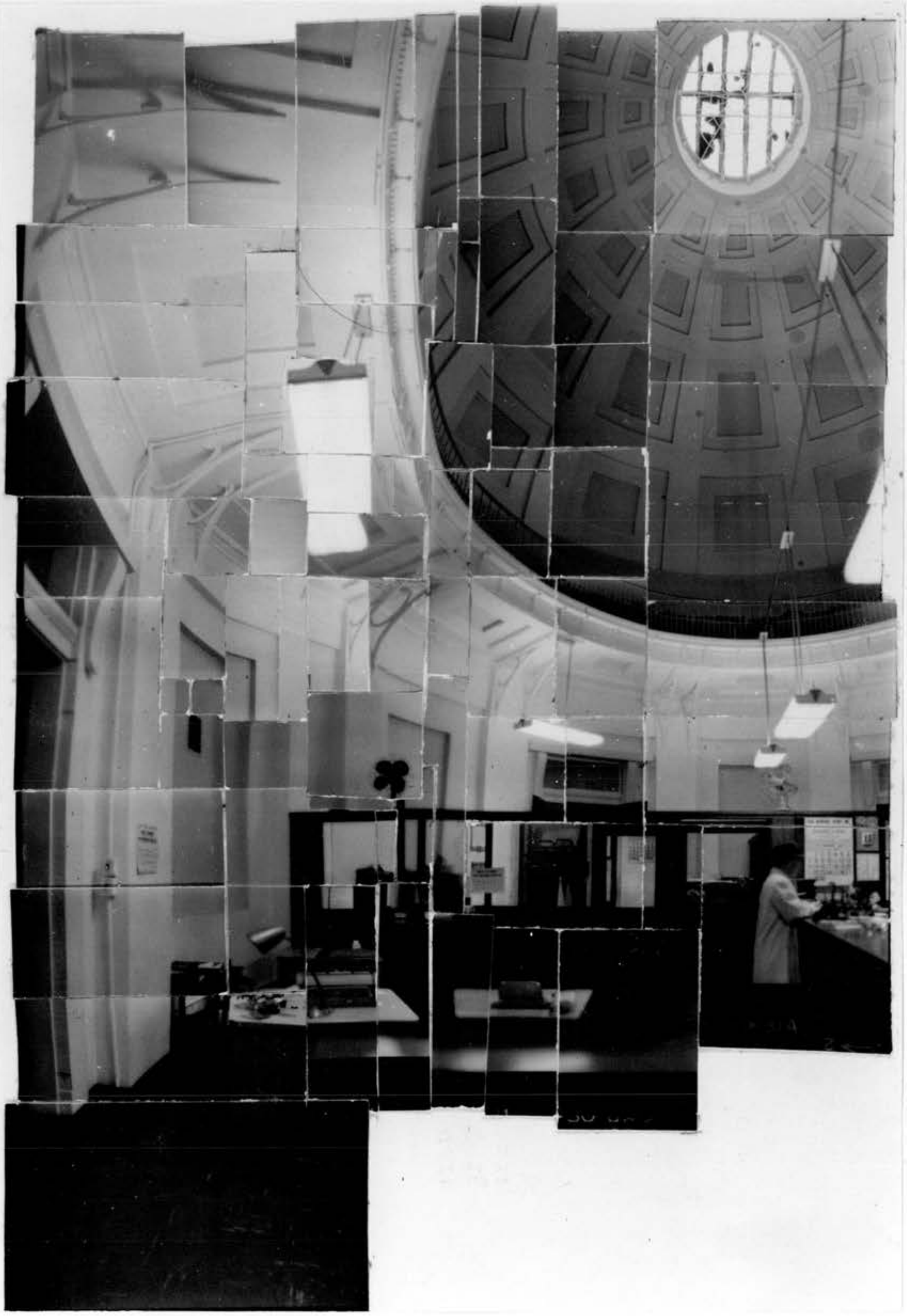


Fig. 10. Progression through Architectural Space. Courtroom, The Montgomery County Court House, Dayton, Ohio.

expense of time and materials in the construction of a model for recording architectural space introduces problems of storage or portability. The designer is then most likely to use a hastily prepared model to test a momentary spatial concept. Assembled with economy he will then dispose of it.

The two-dimensional photograph is a facile method of misrepresenting space, especially sculptural space without geometric definition. Rectangularity in design, encouraged by the architect's drafting equipment, is enhanced with two-dimensional photographic reproduction. The overlay of planes is dominant, the space inferred.

Moretti (1953) photographed models of the internal space volumes of buildings. In these models spaces were constructed as convexities, the structure of the building was left unrecorded. The photographic illustration of this reversal of cavity to convexity uses with advantage the characteristic of the photograph to reproduce planes and convex forms. Fig. 11 shows a photograph of the model of spaces within St. Peter's Basilica, Rome. The method provides an appropriate analysis of individual spaces and shows the relationships between major and minor spaces. It is limited to categorizing space, being incapable of recording sequential progression through the space

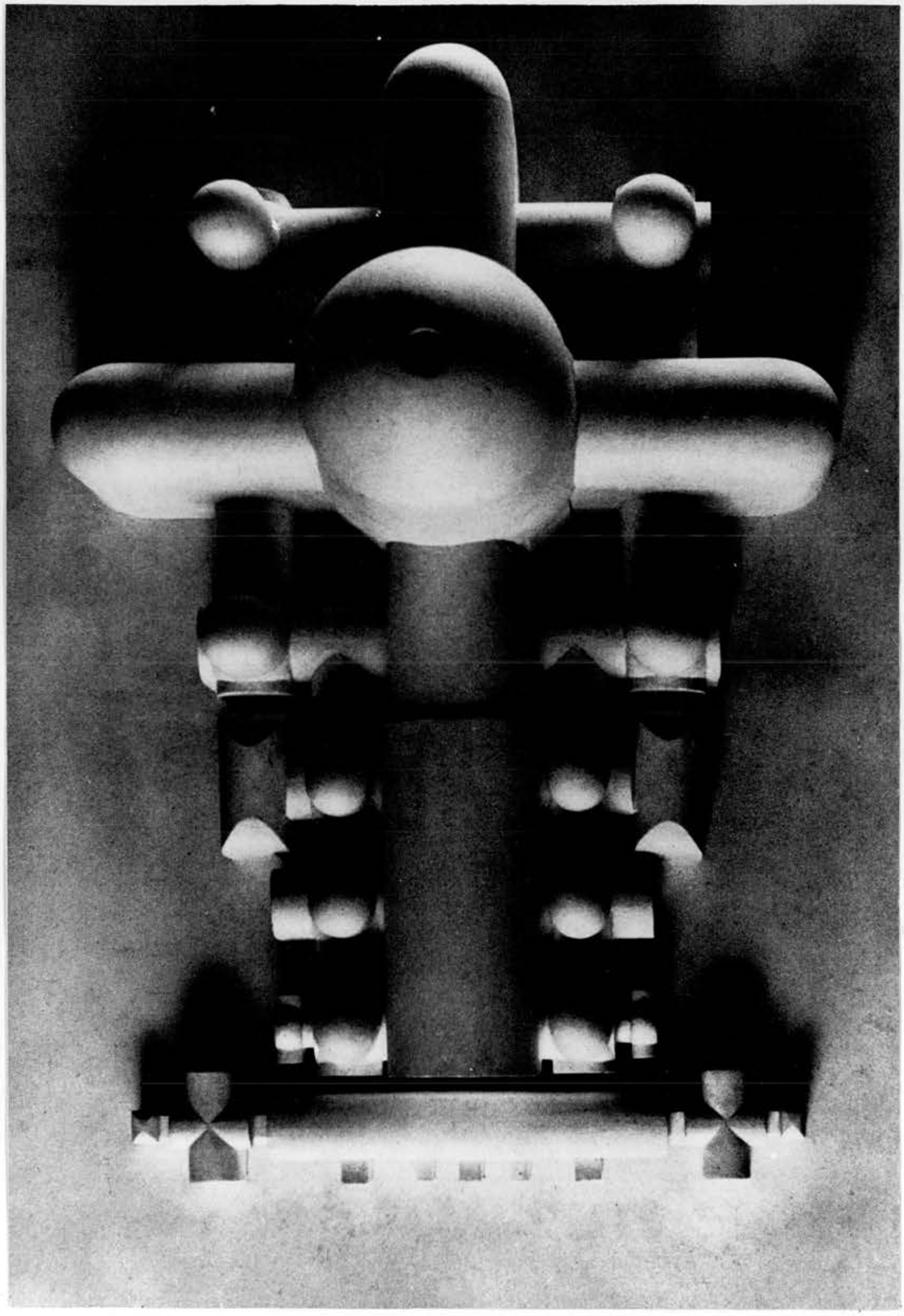


Fig. 11. Illustration of the Convexity of Internal Space Volumes. St. Peter's Basilica, Rome. (From Moretti)

where changes in floor level, openings, or the stacking of several spaces vertically may occur. No indication is given of the spaces that may be experienced simultaneously.

It is the reliance on pictorial cues for spatial meaning that renders the two-dimensional photograph inappropriate for recording space. Factors such as perspective, overlay, light and shade give depth information in the photograph. The same cues contribute to the clarification of space in reality, but only in so far as they enhance or deny the spatial meaning obtained by binocular vision.

An apparent stereoscopic effect may be obtained by variation of a camera focal length so that planes in depth are successively brought into focus, or by successive two-dimensional photography from a moving platform. By exploiting motion parallax the motion picture may produce an impression of depth similar to that obtained by binocular parallax. Retinal image disparity arising from movement in a time sequence replaces that from static spatial arrangement.
The motion picture recording of space, because it depends on constant movement for retinal image disparity, may unduly emphasize the photographer's path through the space. The reconstruction of a static spatial

arrangement, with an accompanying subjective impression of depth, is perhaps more appropriate for architectural studies.

As early as 300 B.C. Euclid reported that the images of objects seen by the two eyes were dissimilar. Retinal disparity was further described by Leonardo da Vinci in the sixteenth century. Wheatstone in 1832 first prepared a series of slightly different drawings for stereoscopic experimentation. After 1850 the measurement of parallax from photographs was possible. Photogrammetry, the science of measurement from photographs, found large scale application during World War II for the preparation of topographical maps.

Spottiswoode (1953) introduced a theory of stereoscopic transmission for cinematographic purposes. This provided mathematical definition for the transfer of a scene, by the storage medium of film, to a reconstruction elsewhere in space. The transmission theory is based on the single hypothesis that the position of an object in space is determined by the point of intersection of rays from the left and right eye to the object. To the left eye, looking along a ray toward a point, the image will appear to lie somewhere on this ray. The same would occur for the right eye. Unless the brain is presented with

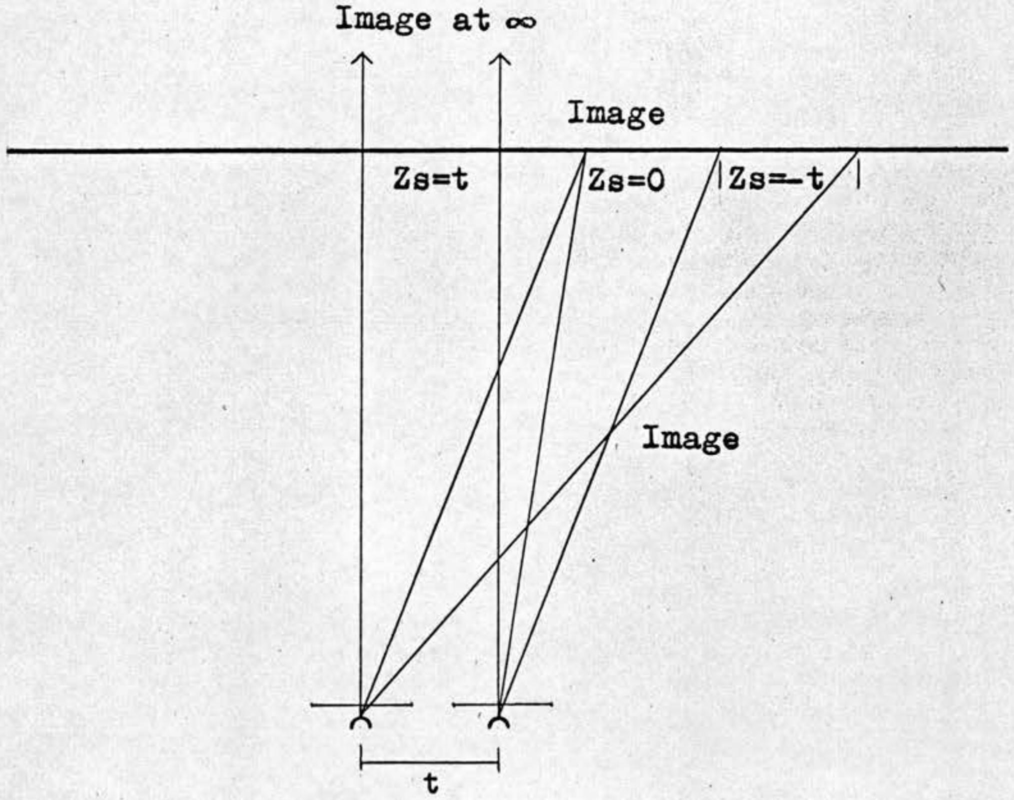


Fig. 12. Screen Parallax.
Theory of Stereoscopic Transmission.
(From Spottiswoode)

conflicting evidence from other sources, the position in depth is determined by intersection of the two rays for this represents the only point where the two sets of information agree.

There are three conditions of intersection that are isolated in the transmission formulae. They are shown in Fig. 12. Rays from each eye remain parallel when a screen parallax Zs is equal to the interocular distance t. The image is then in principle at infinity. For a screen parallax Zs equal to -t, the left and right images are interchanged at the screen and the combined image will appear to be at half the distance from the observer to the screen. A screen parallax of zero will position the image point in the plane of the screen.

Formulae are derived which relate variation in the camera base with object distance and projection distance, and which ensure unit magnification of length, height and depth in the visual model. The distance from the observer to the screen is also important for, assuming all other variables are correctly taken into account, there is only one position at which the impression of space will fulfil the geometric relationships that appeared to the subject in the original scene. The theory of stereoscopic transmission then in practice provides a means to predetermine and control spatial relationships that will appear in projection.

Being derived mathematically, the theory does not take extra-stereoscopic information into account. It has been suggested in Chapter II that visual cues are most effective within the range of binocular uncertainty of depth perception and beyond the distance at which the benefits of binocular vision cease. In the perception of space visual cues may qualify binocular depth information or alternatively, by supplying ambiguity, they may create optical illusions. It is possible in stereoscopic photography and projection to emphasize stereoscopic or extra-stereoscopic information, and conflicts between the two sets of data may present situations unlike reality. An amplification of stereoscopic information reduces the part of visual cues until they have no meaning in spatial definition. This occurs in photogrammetry. And this is the condition that Spottiswoode accepts in the mathematical formulae of the theory of stereoscopic transmission. But there would be a specific combination of stereoscopic and extra-stereoscopic variables which would record the geometry of a space as it is apparent to a subject in a real situation. Physical distance would again be modified by binocular uncertainty of depth perception and so become subjective apparent distance.

For a given camera base, the relative contribution of stereoscopic factors would become more important in conveying a sense of space as the fidelity of a photographic transmission system is lowered. Gains from the principles of stereoscopy would be greatest in still photography where the contribution of motion parallax is absent, or in a transmission medium of low quality pictorial reproduction. They would be less in the motion picture where pictorial rendering is of a high quality, and least of all in Cinerama or Circlarama projection where an endeavour is made to recreate the visual location of the observer by surrounding him with a curved projection screen.

The methods of stereoscopic projection may be divided according to whether image separation occurs at the observer's eyes or at the screen.

Separation of the left and right image at the eyes is achieved by a rotating disc or shutter device, anaglyphic filters, or polarizing spectacles. In the first case a rotating disc is designed on the basis of persistent vision — intermittent light of more than thirty cycles per second is seen as continuous light. The device is synchronized with the projector and the intermittent light output. Image separation by colour necessitates the manufacture of filters which transmit half of the visible spectrum. Red filters to absorb light of wavelengths less than 600mμ are obtained without difficulty. A blue-green filter to absorb all wavelengths greater than 600mμ is in practice difficult to obtain. The display from anaglyphic image projection is monochromatic. The only practical method of image separation for reconstruction of a scene in colour is that which employs polarization. Light is polarized when passed through a filter of plastic film in which long and thin molecules are laid end to end. One phase of the light passes through the filter, the remaining is absorbed by the molecules. Light from two projectors is polarized in mutually perpendicular planes and the screen images are separated by corresponding analysing filters placed before the eyes. Polarization does not reduce the pictorial image quality in definition or in the rendering of colour.

The separation of images at the screen requires in principle the projection of an infinite number of spatial images. These must be integrated from microscopically small components. The principles of integral photography were outlined by Lippmann in 1908, and the procedure has been highly refined by Sokolov and Ivanov in the Soviet Union.

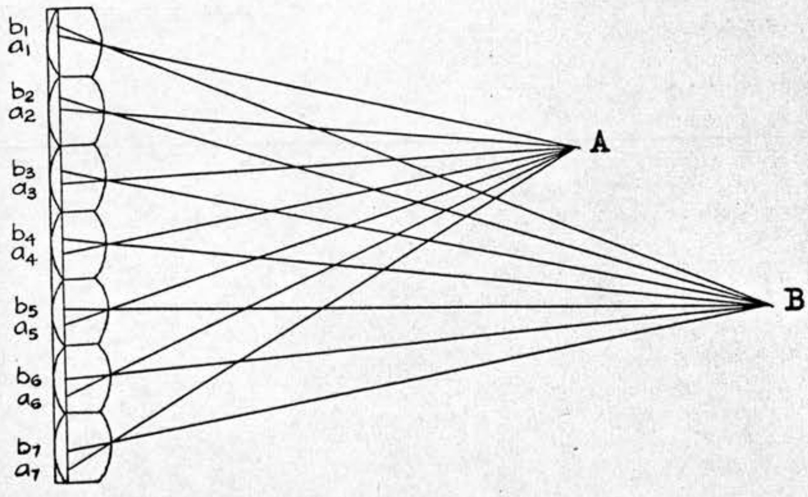
Lippmann proposed a photographic plate consisting of a large number of very small lenses, each forming a microscopic image on to a light-sensitive emulsion. Due to variation in the position of the lenses on the photographic plate, the parallax in each image was different. The plate containing the lenses constituted the objective and this was placed directly in front of the object with its refracting surface towards it.

The preparation of the photographic plate is illustrated in Fig. 13(a). Object point A produces a large number of images represented as a_1, a_2, a_3 ... From another object point B images b_1, b_2, b_3 ... are formed. The exposed plate is developed and a diapositive obtained by optical printing. Fig. 13(b) illustrates the reconstruction from the diapositive.

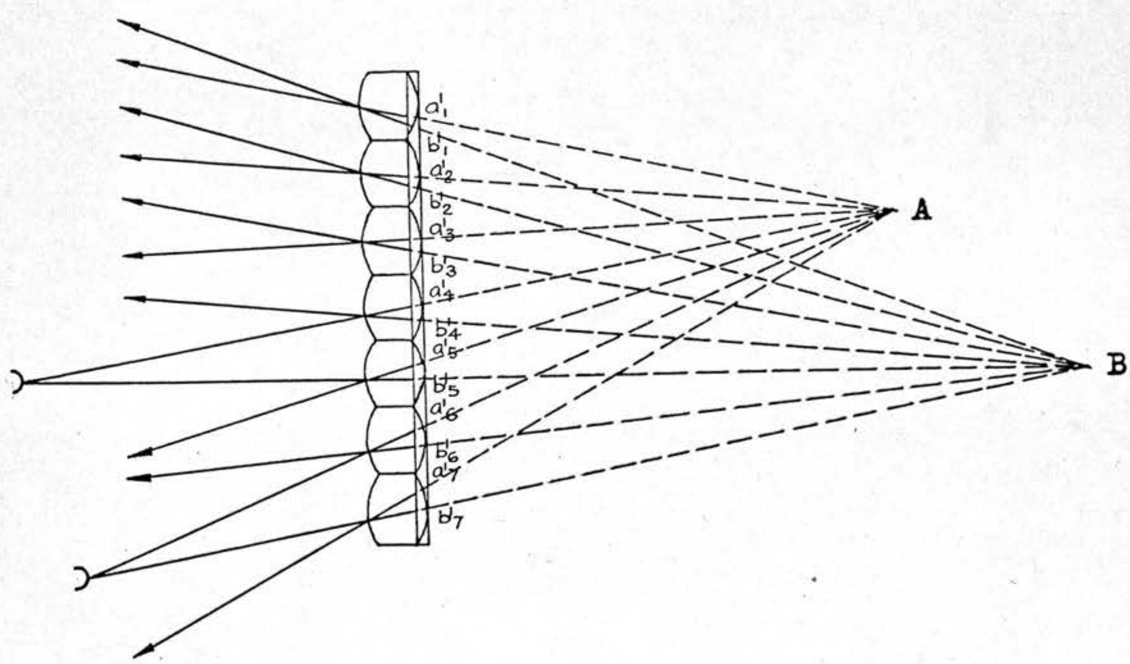
Sokolov (1911) dispensed with the need for a diapositive and formed a large number of elementary images by a faceted mirror. A normal camera objective was used to photograph these images.

The most successful experiment in integral photography, using spherical lenses and a raster or grid plate, was reported by Ivanov in 1948. The diameters of the lenses were 0.3mm and the focal lengths 0.5mm. Over two million lenses were located on the plate.

The raster is designed to physically exclude the opposing image to each eye but permit free observation of the appropriate image. The display consists of a series of narrow strips which represent alternately the images to the left and right eye. This is shown in Fig. 14.



(a) Photographic Plate Recording.



(b) Diapositive Reconstruction.

Fig. 13. Integral Photography.
(Adapted from Valyus)

> "The spectator should get the impression he would obtain by looking at the panorama through an open window. As he approaches the integral optic image he sees, just as if he were approaching the window, that objects outside approach, the panorama expands, and the perspective and angular subtense alter. As he moves to one side of the window he sees other objects, he can look around them to the side and see what there is behind and as he does so different aspects are revealed."[24]

The above description has not yet been fully realized in projection. For any viewing position the observer is required to find the best view point and

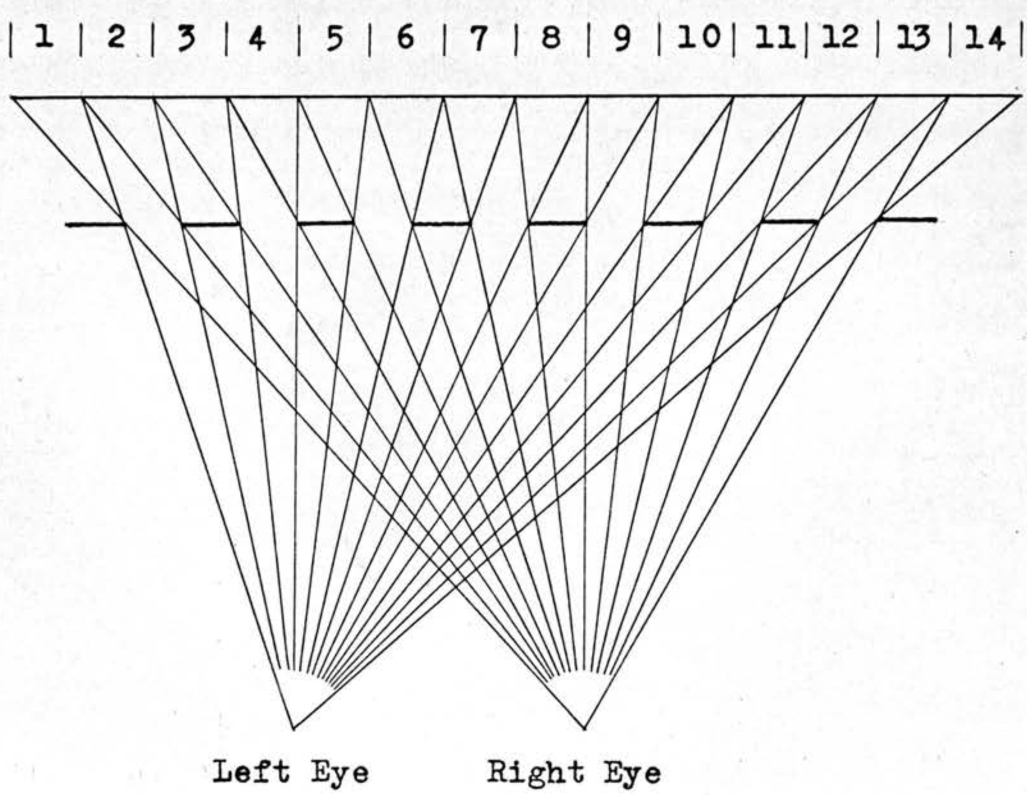


Fig. 14. Raster Method of Integral Photography.

[24]N. A. Valyus, Stereoscopy (London: Focal, 1966) 87.

maintain fixation free from movement. For best results the head is clamped.

The invention of the laser has implemented the study of holography propounded by Gabor in 1947. The method analyses and later reconstitutes all information present in light.

> "Only a very small region of a single light source is self-consistent in phase or 'coherent', a region so small that its details cannot be resolved ... because of the finite wavelength of light. All this is changed by the invention of the laser, the very unconventional source whose light is coherent over a large volume and long periods."[25]

Leith and Upatnieks (1963, 1965) introduced two sets of coherent rays — one to indirectly expose a photographic plate after reflection from the objects, the other to expose the same plate directly. The second set of rays, or reference beam, was reflected by a mirror so as to by-pass the objects. On reaching the photographic plate this reference beam produced, by means of interference effects, a visible display of the wave pattern of light. Every part of the plate received light from every point on the object and from the mirror. The coherent light rays were identical in length and proceeded in step. At some points on the

---

[25] D. Gabor, "Holography, or the 'Whole Picture'" <u>New Scientist, 29,</u> (1966) 74.

photographic plate the crests of waves reflected by the object coincided with the crests of waves in the reference beam. The two rays reinforced each other and exposed the photographic emulsion at that point. At other points the crests of waves reflected by the object coincided with the valleys of waves in the reference beam. They cancelled so that the plate received less exposure.

The interference pattern or hologram contains all data of light reflected from the objects. By passing two laser beams back through the hologram the rays may be focused by a lens to form a visual model of the original scene. The reconstructed waves that propagate outward from the hologram are indistinguishable from the original waves and behave as these would have done had they not been interrupted by the photographic plate. Laser photography therefore provides a reconstruction of outstanding fidelity to the original scene.

> "The identity between the reconstructed waves and the original waves that impinged on the plate when the hologram was made implies that the image produced by the hologram should be indistinguishable in appearance from the original object. This identity is in fact realized. The virtual image, for instance, which is seen by looking through the hologram as if it were a window, appears in complete three-dimensional form."[26]

---

[26] E. N. Leith and J. Upatnieks, "Photography by Laser," SC. Amer., 212, (1965) 30.

The reconstruction includes all visual properties of the original scene. Movement of the observer leads to variation in perspective with parallax effects for near and distant objects. As in reality, the observer may view previously hidden objects by movement of the head to the side of a foreground object. In fixating near and distant objects the eyes perform accommodative movements for adjustment in focus.

The application of laser photography to the recording of architectural space holds considerable potential. The delay in this application is dependent on the change in scale of recording small objects in space to that of recording the ranges in distance of architectural space.

The visual model obtained by laser and integral photography differs from that received from stereoscopic film projection using polarized light. Movement of the observer in laser or integral methods leads to variation in perspective. In the projection of a stereoscopic film variations in viewing position do not alter the perspective of the display. Instead, the complete display pivots on the screen as shown in Fig. 15.

Accommodative eye movements do not occur when viewing a three-dimensional display obtained by either the integral or polarization method. All planes in depth remain focused on the screen at the viewing distance. Eye movements of convergence, however, occur as in reality. The isolation of convergent and accommodative eye movements, difficult to achieve in the perception of real space, occurs normally without difficulty in stereoscopic photographic representation.

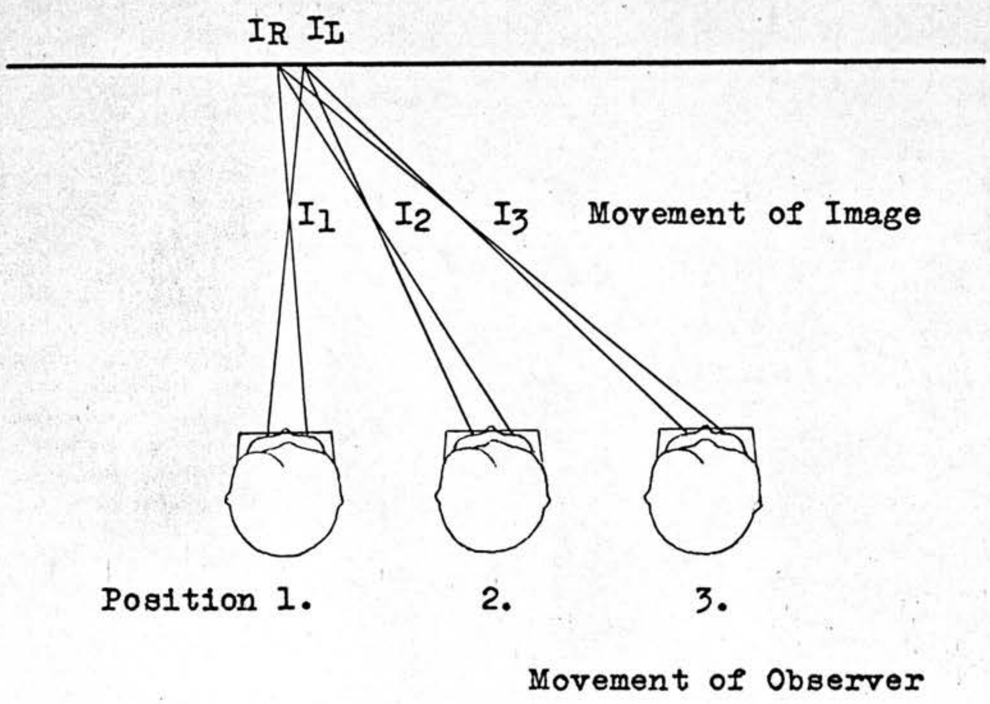


Fig. 15. Stereoscopic Film Projection.
Movement of Observer and Image.
(From Spottiswoode)

IV. VISUAL DISPLAYS OF SPATIAL SEQUENCES

Movement of a subject is integral with spatial definition and experience. The subject's path in time and space is made of linked points. Each point is unlikely to be of equal importance for, although the subject may progress through space at a uniform speed, spatial definition is largely gained by abrupt stimulation. In addition to points of greater visual interest there may be points in the spatial sequence which tend to evoke a subjective response compatible with the subject and mood. The spatial sequence may then modify continuous progression in time with suggested points of rest and elements of passage.

Each point in the spatial sequence may provide a subjective response. The sequential experience is more, less or similar to the aggregate of individual experiences. Despite the fact that there may be physical continuity of spatial sequences, there may be points at which individual experiences or groups of experiences seem to begin and end. In this way it would be possible to isolate a spatial sequence.

For the measurement of objective evidences in perception and the subjective scaling of responses binocular vision is essential. Unlike stereo-photogrammetric methods for measurement of actual dimensions, the concern here is for recording apparent dimensions and proportions as seen in normal vision. Borchers (1962) first reported the application of stereoscopic photography to the classroom study of architectural space and form. It has been shown in Chapter II that, for normal vision, an error of depth perception increases as the square of viewing distance. Architectural illusion is possible due to the imperfection of binocular vision. Architects in the past have taken account of this fallibility by compensating for, or exploiting, errors of perception. The architects of Classical Greece introduced compensation for optical illusion which contradicted the structure's apparent regularity. The architects and theatre designers of the Baroque period exploited the error of depth perception by accentuated perspective. An attempt to create an optical illusion in architectural space can only be assessed by attentive binocular vision.

For the present study, methods of stereoscopic photography have been selected to provide visual displays of spatial sequences. And the essential object of stereoscopic photography in this case is to record and reproduce an optical model which possesses the same degree of uncertainty in the perception of distances as does our binocular vision in space.

Series of stereoscopic slides have been photographed in the field and projected by two Kodak Carousel S projectors. A stereoscopic motion picture has been obtained with a 16mm Bolex camera and stereo attachment. This was projected through a Bolex stereo projection lens fitted to a 16mm Bell and Howell projector. Polarization of light provided image separation in both cases.

Experiments carried out by the Institute of Biological Physics, the Academy of Sciences in the Soviet Union have shown that, despite the absence of accommodative eye movements, there is validity in eye movement analysis from stereoscopic projection. Yarbus and Goltsman (1955) projected geometric figures from a bi-objective projector.

> "The distance from the observer at which the stereoscopic image 'came out' into the room was noted. The real object was then located in the pre-screen space at this distance. The observer in turn fixated the real object and the stereoscopic image. On all occasions the degree of convergence on fixation of the real objects and the stereoscopic images was the same."[27]

---

[27] A. L. Yarbus and N. I. Goltsman, "The Movements of Eyes in the Perception of Images in a Stereoscopic Cinema," Transactions of the Inst. Biolog. Physics, I, (Moscow, 1955) 175. Transl. Kinrade, Dept. Russian Language, Edin. Univ.

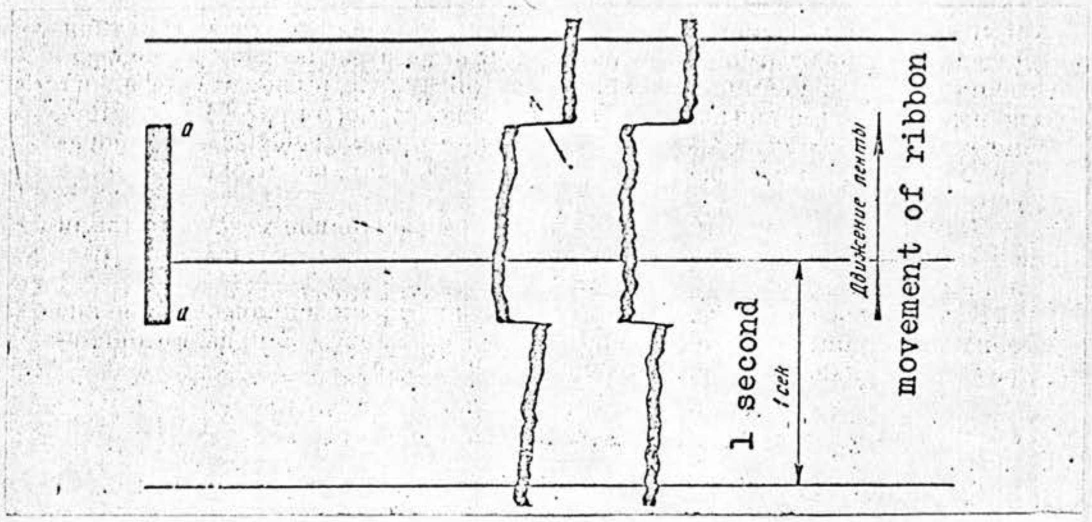
An eye movement recording of this experiment is given in Fig. 16(a). Yarbus and Goltsman also obtained eye movement recordings from a subject viewing a stereoscopic motion picture, Fig. 16(b).

> "An excerpt of the colour stereoscopic film 'Under a Blue Cupola' was projected. The observer was seated 5.8 metres from the raster screen, 1.2 metres by 1.2 metres in size. In the excerpt there are sequences in which the images of objects shift not only beyond the screen but also in the space before the screen. During the time the observer viewed the excerpt of the stereoscopic film and the eye movements were recorded, the experimenter fixed by a special marker the separate moments of the action of the plot and also the 'coming out' of the images into the room. In the figure [Fig. 16(b)] is shown portion of the eye movement recording on which are clearly seen the fixations, the 'leaps' and traces giving the convergence of the eyes, that is, all those movements which accompany the perception of real objects.
>
> "The movements of the eyes of the observers on perceiving stereoscopic images are analogous to the movements of the eyes on perceiving real objects."[28]

The stereoscopic motion picture combines the control of depth impression with sequential movement. The positioning of the camera in space by the photographer is the outstanding disadvantage of any photographic technique. The motion picture emphasizes this by providing a path through space controlled by the photographer. The problem is particularly pertinent

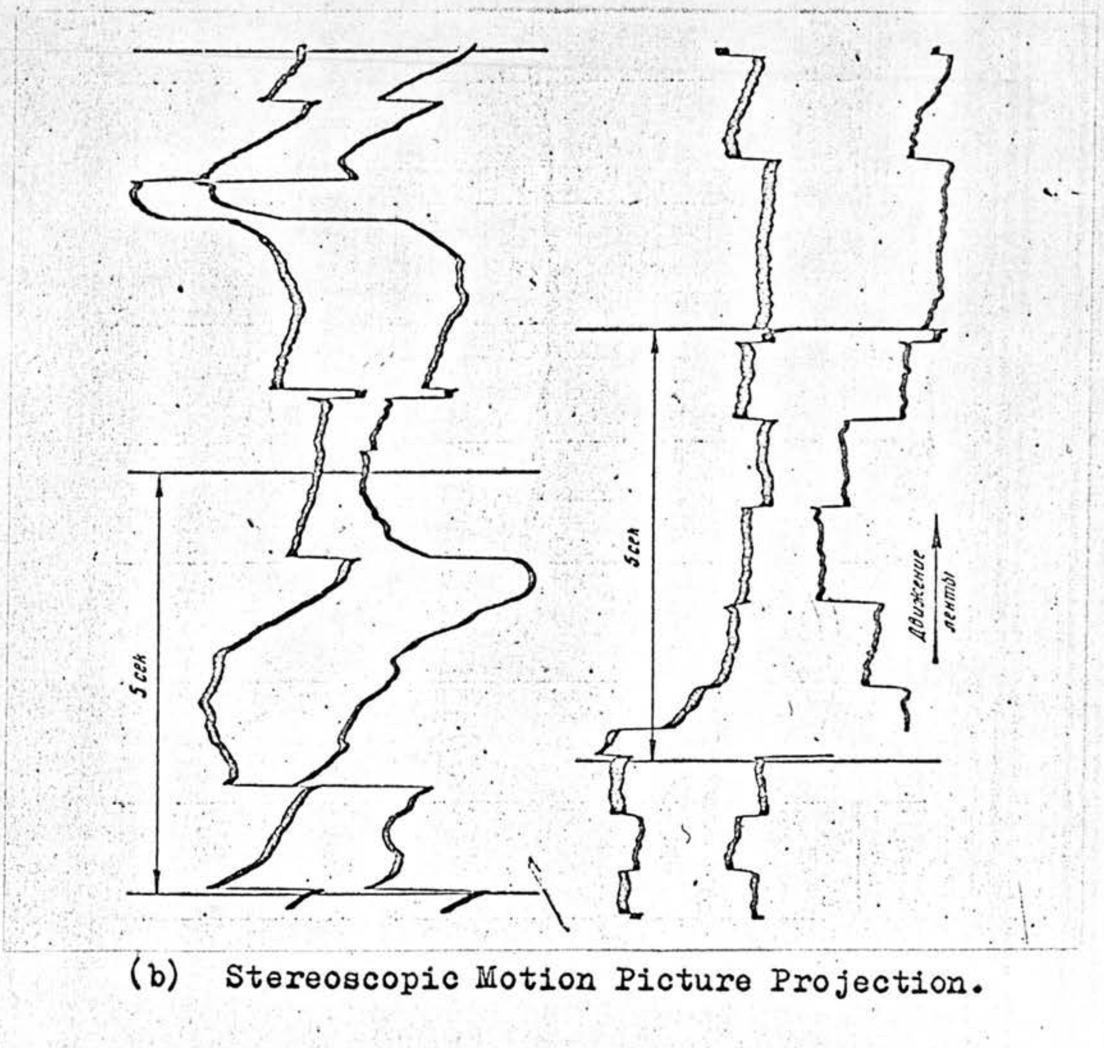
---

[28] Ibid., 177.



(a) Stereoscopic Slide Projection.

During the recording of eye movements the line a-a recorded the duration of stereoscopic image projection.



(b) Stereoscopic Motion Picture Projection.

Fig. 16. Eye Movement Recordings of Convergence from Displays of Stereoscopic Photography. (From Yarbus & Goltsman)

when the architect has not designed space with sequential and subjective experience in mind or when his intentions are not clear. On the one hand the subject may wander in architectural space; on the other he may be led through a designed spatial sequence. In an attempt to lessen the discreteness of a photographer's path, the selection of spatial sequences for this study has been limited to examples where spaces, individually or in series, have been designed to be experienced in a particular way.

V. EYE MOVEMENT RECORDING

The physiologist and psychologist have given particular attention to methods of eye movement recording. At first the methods supplemented direct observation.

The subjective analysis of after-images was introduced by Lamansky in 1869. At first the retina was stimulated during eye movement by intermittent light and the number of after-images was taken to provide a measure of the length of time required for movement. Guillery in 1893 exploited tachistoscopic illumination to distinguish the form of an after-image. A disc with four slits was rotated by clock-work behind a dark screen. Circular, semi-circular and rectangular apertures were made in the screen and the after-images of these illuminated openings provided a more reliable definition of eye movement. The methods were subjective and there was no provision for permanent records that could be later analysed.

Mechanical devices were attached to the eye.

These included corneal cups, levers and air capsules. Ahrens in 1891 placed a close-fitting ivory cup on to the cornea after it had been strongly cocainized to relieve the great pain and excessive tear secretion. Delabarre (1898) formed a plaster cast over an artificial cornea. The cast was then trimmed to reduce its weight but retain a smooth concave surface that could be pressed against an anaesthetized eye. A thin wire ring was cast into the plaster to form a hole of similar diameter to that of the pupil. A light thread was attached to a projection of the wire and this activated a recording lever. Air capsules were later placed against the eye. The protuberance of the cornea led to variation in air pressure as the eye moved under the capsule. The changes in air pressure were recorded on smoked paper.

A mechanical-photographic technique by Rodin and Newell (1934) recorded the changes in distance between a marker attached to the bulbar conjunctiva of an anaesthetized eye and a marker on the canthus. As the eyes were bandaged x-ray photography provided the means for subsequent measurement.

The first photograph of eye movements is attributed to Dodge in 1899. Dodge and Cline (1901) described the photographic method. A continuous photograph of a horizontal line across the eye was obtained by a slowly falling photographic plate. The lines of demarcation between pigmented and unpigmented parts of the eyes were poorly defined. This led Dodge and Cline to photograph a sharply defined reflection from the eccentric surface of the cornea. From this introduction, corneal reflection has become the most widely used method for the precise registration of the direction and duration of eye movements. The method is capable of registering both eyes simultaneously.

Judd (1907) first investigated the movements of convergence and divergence by a double photographic record. Two cameras alternately photographed a small patch of Chinese white which was attached directly to the cornea. Because of a tendency for the patch to shift slightly due to eye and lid movements and gravitational effects, later experimenters including Totten (1926) prepared adhesive platelets for point definition. Reflection from contact lenses, described by Cornsweet (1958) and Ditchburn (1959), has provided the most sensitive method for recording eye movements and has had particular application to the study of miniature eye movements and their relationship to visual perception.

Comfort and Dearborn in 1927 and Tinker (1931) developed recording equipment using the principle of corneal reflection. The Iowa eye movement camera, described by Jasper and Walker (1931), was modified to record simultaneous binocular movements on continuously moving film. Clark (1934) modified the Dodge apparatus to record horizontal and vertical binocular movements at the same position on a single film.

> "The rays from the peripheral part of the lens are focused on sensitive paper without further change. They record horizontal movements as a horizontal displacement. The central rays are focused to one side of the peripheral rays by means of a flat prism; but their motion is rotated 90° by the total reflecting prism, i.e. a vertical movement of the eye will also cause a horizontal displacement on the film."[29]

Taylor (1937) devised the Ophthalmograph, a portable recording instrument manufactured by the American Optical Company. The apparatus was mounted on an adjustable standard and was provided with head and forehead clamps and a chin rest. The light ray was reflected from the cornea, focused onto two telescopic lens systems, and photographed. The ophthalmograph has been widely used for recording eye movements during reading. By the introduction of a

---

[29] B. Clark, "A Camera for Simultaneous Record of Horizontal and Vertical Movements of Both Eyes," Amer. Journ. Psychol., 46, (1934) 325-326.

dove prism, similar to that described by Clark, fixations of convergence have been recorded.

The ability to demonstrate corneal reflection on a closed circuit television system has readily provided a two-dimensional graphical representation of eye fixations. A white dot defines eye position and this is superimposed on to a display of the field of view. Mackworth and Mackworth (1958) and Mackworth (1962) reported the development of a portable Eye Marker Camera. An 8mm motion picture camera, mounted to a helmet, recorded the field of view by periscope and optically superimposed the reflection from the cornea. A continuous graphical record of the field of vision replaces the need for complex recording and analysis of head movements or for rigid fixing of the head.

Direct cine photography has been used in certain investigations. Jones in 1959 used a light head-mounted camera to study torsional movements of the eye ball under various conditions of body rotation, including those during aircraft flight.

The history of eye movement recording apparatus has led from the mechanical, with excessive interference to the subject, to the photographic and most recently to the electronic. Electro-oculography is now characterized by minimal apparatus in the field of view of a subject.

Schott in 1922 attached wires as electrodes to a cocainized eye. The electrodes were attached to the inner and external canthus and connected by a string galvanometer which provided a characteristic deflection for each eye movement. Meyers (1929) and Jacobson (1930) independently developed the galvanometric method. They both attributed their results to the summation of action currents from the extrinsic ocular muscles. Kohlrausch (1931) found that a potential difference exists in the eye. This was attributed to divergent metabolic rates. Mowrer, Ruch and Miller (1936) clearly demonstrated that the galvanometric method was not dependent on muscular activity but on a persistent potential difference between the front and back of the eye, the latter being consistently negative with respect to the former. The field from the dipole changed with eye rotation. Electrodes placed on the skin surface near the eye detected changes in direct potential. Shackel (1960) has shown that these voltages are linearly related to the angle of eye rotation for excursions of at least 30° to the left or right of centre.

Marg (1951) provided a comprehensive review of the development of Electro-oculography. Shackel, Sloan and Warr (1958) investigated the sensitivity of the technique and the effect of skin and electrodes on sensitivity. The skin generates potentials within the same general frequency band but of considerably greater amplitude than the eye potentials. These skin potentials are also transmitted to the recording system by the electrodes. The electrolyte/metal-salt/metal electrode which must be used is an active electro-chemical system and it was shown that this produced noise, in the form of slow drift potentials, again of similar general characteristics to the eye signal. Shackel (1959) developed a method to diminish noise potentials from skin and electrodes. A shallow depression was made in the skin surface and this provided a direct conducting pathway through the epidermis. Saline jelly electrolyte was found to 'short circuit' the skin surface and the sweat glands through the break in the epidermis. The skin membranes were then depolarized over the whole area covered by the contacting electrode.

Shackel used a suction cup electrode which was attached to the external canthus for horizontal movements. Sverak and Peregrin (1963) have reported a contact suction electrode of thin convex silver sheet, 6mm in diameter, which was attached to the bulbar conjunctiva and held in position by low pressure.

Shackel (1960) demonstrated the use of a head-mounted television camera for Electro-oculography recording.

Smith and Warter (1959) reported a photo-electric technique for measuring eye movements. A lens placed laterally 45^{o} to the eye focused the image of a portion of the iris and schera onto a surface containing a slit 1mm wide and 1cm long. A photo-cathode of a multiplier tube was positioned behind the slit. As the eye moved laterally more or less of the iris was imaged on the slit. The difference in reflectance between the iris and the schera governed the total light passing through the slit, and this passage of light was proportional to the angular rotation of the eye.

FEASIBILITY STUDIES

VI. SUBJECTIVE DEPTH IMPRESSION

In stereoscopic photography an increase in the camera base increases the limit of stereoscopic vision and enhances the impression of depth. Such changes in a display lead to changes in the apparent scale of the object space.

For a selected camera and film the focal length of the lens and the resolving power of the lens and film are kept constant. Depth impression during stereoscopic projection is then determined by the camera base used in photography. The commercial stereo camera, because it incorporates a base equal to an average interocular distance of 2.5 inches, is able to present an acceptable depth representation for only a limited range of distances from the camera. Manufacturers have been concerned with stereoscopic depth of field.[30] Minus lenses are added to the normal lens for intermediate and close-up photography. The possible ranges of distance are particularly

---

[30] Stereoscopic depth of field is the terminology used by Bolex to describe the range of distances which are to be recorded simultaneously by the stereo camera and later viewed without difficulty during projection.

restrictive with close-up lenses. The stereoscopic depth of field for the Bolex 16mm stereo attachment with minus lenses is from 1.5 feet to 3 feet for close-up photography, and from 2.5 feet to 7 feet for intermediate photography. But the normal lens is used for distances from 4 feet to infinity. Restriction of a depth impression acceptable for representing architectural space limits distances of stereoscopic photography more severely than the stereoscopic depth of field criterion. In the opinion of the writer the Bolex Yvar 16mm motion picture stereo attachment presents a satisfactory depth impression for distances between 20 feet and 80 feet from the camera. 35mm stereoscopic slide photography, unlike motion picture photography, is unable to supplement depth impression from binocular parallax with that from motion parallax. The projection of slides photographed with commercial stereo cameras, in which is incorporated a camera base equal to the interocular distance, records depth to approximately 30 feet. Foreground objects are seen in three dimensions but more distant architectural elements in the space are seen as flat stage backdrops.

A series of experiments have been carried out by the writer using stereoscopic slides from two identical lens systems and from a single objective moved along a tripod mount. Parallel and convergent photography were used for 35mm slide and 16mm motion picture cameras. Stereoscopic photography with convergent camera axes at times resulted in noticeable curvature to horizontal lines when projected to a flat surface. The projection of 35mm stereoscopic slides of architectural space has shown that in photography a camera base greater than the interocular distance was required in order to compensate for the lack of resolving power of the film and lens as discriminated at the scale of the projection screen. Minolta SR-7 cameras with Auto Rokkor 1.4/58mm lenses and Ektachrome 64 ASA film were used for all stereoscopic slide photography. Shutter speeds were varied to suit f.16 aperture settings. Two Kodak Cine Special 16mm motion picture cameras, linked mechanically, were used for stereoscopic motion picture photography in addition to the Bolex camera and stereo attachment.

From the results of the above experiments a feasibility study was prepared to ascertain whether a depth impression based on the writer's findings would be acceptable to a group of architects. A series of stereoscopic slides was photographed of survey poles placed in an open field and in familiar architectural space. From the stereoscopic information and visual cues recorded in the displays each subject recorded his impressions of depth representation. Six stereopairs were projected and viewed by five architects. The displays are illustrated in Fig. 17(a)-(f) and the questionaire is given in Table II.

From the results Table III it is seen that, for distances 25 feet to 50 feet from the camera to object, a camera base of six inches provided a subjective impression of depth that was reasonably acceptable to all subjects. The stereoscopic photography of displays of architectural space to be used in this study has been taken according to Table IV.

Left image of stereopair.

Right image of stereopair.

(a) Display 1. Camera base = 12 inches.

AB = BC = 10 feet.
AB to camera = 22 feet.

Fig. 17(a)-(f) Displays for Subjective Impression of Depth Questionaire.

Left image of stereopair.

Right image of stereopair.

(b) Display 2. Camera Base = 8 inches.

AB = 10 feet.
BC = 5 feet.
AB to camera = 22 feet.

Fig. 17(a)-(f) Displays for Subjective Impression of Depth Questionaire.

Left image of stereopair.

Right image of stereopair.

(c) Display 3. Camera base = 6 inches.

AB = BC = 10 feet.
AB to camera = 22 feet.

Fig. 17(a)-(f) Displays for Subjective Impression of Depth Questionaire.

Left image of stereopair.

Right image of stereopair.

(d) Display 4. Camera base = 5 inches.

AB = 8 feet.
BC = 24 feet.
AB to camera = 25 feet.

Fig. 17(a)-(f) Displays for Subjective Impression of Depth Questionaire.

Left image of stereopair.

Right image of stereopair.

(e) Display 5. Camera base = 8 inches.

Between poles = 9 feet.
Poles to door = 9 feet.

Poles to camera = 44 feet.

Fig. 17(a)-(f) Displays for Subjective Impression of Depth Questionaire.

Left image of stereopair.

Right image of stereopair.

(f) Display 6. Camera base = 8 inches.

No survey poles.

Fig. 17(a)-(f) Displays for Subjective Impression of Depth Questionaire.

Table II. Subjective Impression of Depth Questionaire.

In each of the following four displays there will be four survey poles:

D   C

A   B

In each case ABCD forms a rectangle in plan in which A and B should appear to be at the same depth but in front of C and D. The distance to C and D should appear similar.

The survey poles are six feet in height.

DISPLAY

1. The four poles form a square 10 feet x 10 feet. Please indicate by X whether the impression of depth appears exaggerated, accurate or reduced.

pronounced exaggeration	____
slight exaggeration	____
accurate	____
slight reduction	____
pronounced reduction	____

2. The distance between A and B is 10 feet. What does the distance between A and D appear to be?

____

3. The four poles form a square 10 feet x 10 feet.

Please indicate by X whether the impression of depth appears exaggerated, accurate or reduced.

pronounced exaggeration	____
slight exaggeration	____
accurate	____
slight reduction	____
pronounced reduction	____

4. Please draw the plan of the four poles giving apparent dimensions.

Please indicate letters to all survey poles.

The entrance to the David Hume Tower will be recognized in the following two displays:

DISPLAY

5. Please indicate the apparent distance from the survey poles to the entrance doors.

____

6. Please indicate by X whether the impression of depth appears exaggerated, accurate or reduced.

pronounced exaggeration	____
slight exaggeration	____
accurate	____
slight reduction	____
pronounced reduction	____

Table III. Results.
Subjective Impression
of Depth Questionaire.

Subjective Impression of Depth.	DISPLAY 1. Base = 12 ins. Subject 1	2	3	4	5	DISPLAY 3. Base = 6 ins. Subject 1	2	3	4	5
pronounced exaggeration										
slight exaggeration	X	X	X		X			X		
accurate				X		X	X		X	X
slight reduction										
pronounced reduction										

Subjective Impression of Depth.	DISPLAY 6. Base = 8 ins. Subject 1	2	3	4	5
pronounced exaggeration					
slight exaggeration		X	X		
accurate	X			X	X
slight reduction					
pronounced reduction					

Subject	DISPLAY 2. Base = 8 ins. AD	DISPLAY 4. 5 ins. AB	AD	DISPLAY 5. Base = 8 ins. Poles to door
1	6 feet	8 feet	16 feet	8 feet
2	4	10	24	9
3	7	8	24	12
4	5	8	20	8
5	4	8	18	10
Actual Measurement	5	8	24	9
S.D.	1.3	0.9	3.6	1.7

Table IV. Camera Base.
Stereoscopic Slide Photography.

Range of distances in space to be recorded	Camera base
25 feet - 50 feet from camera	6 inch
25 feet - 100 feet from camera	7
100 feet - horizon	8

VII. SUBJECTIVE RESPONSE

"There is ... a typical emotional reaction to being below the general ground level and there is another resulting from being above it. There is a reaction to being hemmed in as in a tunnel and another to the wideness of the space. If, therefore, we design our towns from the point of view of the moving person (pedestrian or car-borne) it is easy to see how the whole city becomes a plastic experience, a journey through pressures and vacuums, a sequence of exposures and enclosures, of constraint and relief.

"The crowding together of buildings forms a pressure, an unavoidable nearness of detail, which is in direct contrast to the wide piazza, square or promenade, and by the use of such narrows it is possible to maintain enclosure without forbidding the passage of vehicles and pedestrians. In this way the articulation of the city into clear and well-defined parts is made possible. In its own right narrowness has a definite effect on the pedestrian, inducing a sense of unaccustomed constriction and pressure."[31]

"We adapt ourselves instinctively to the spaces in which we stand, project ourselves into them, fill them ideally with our movements."[32]

---

[31] G. Cullen, Townscape (London: Architectural Press, 1961) 12, 45.

[32] B. Zevi, Architecture as Space (New York: Horizon, 1957) 217.

> "Movements of air volumes bear out the role of the human beings in the buildings ... hence the channelling and the amplification of our own being that we experience in a successful interior."[33]

In describing the subjective responses to architectural spaces these writers have adopted as terminology the words adaptation, channelling, amplification, pressures, vacuums, constraint, constriction and relief.

Hall (1966) analysed "The Anthropology of Space" from the assumption that the allotment of space is one of the simplest and possibly the most basic element in organizing the activities of a group.

> "Each organism, no matter how simple or complex, has around it a sacred bubble of space, a bit of mobile territorality which only a few other organisms are allowed to penetrate and then only for short periods of time.
>
> "Changes in the bubble caused by outside influences [such as architecture] may force on the occupant the feeling that he has been thrown into aggressive relationships with strangers or has been sealed off and removed from people."[34]

The size of "the bubble" could be dependent, in part, on position in social heirarchy, activity,

---

[33]R. Arnheim, "Inside and Outside in Architecture: A Symposium," Journ. Aesth. & Art Crit., 25:1, (1966) 5.
[34]E. T. Hall, "The Anthrpology of Space," Arch. Review, 140, (1966) 163.

emotional state and cultural inheritance. Classification as to the type of person, previous conditioning and mood will be considered in a later chapter. The concern at present is the evidence of basic relationships between man and space. And Hall's description of an individual bubble links the several descriptions of subjective responses arising from spatial experience. Adaptation, amplification, pressure, constriction and relief describe the effect of outside forces on an individual bubble of space.

What is likely to be the range of subjective responses when external influences impinge on each bubble of space? What responses change as the bubble shifts from one size to another with different situations, relationships and emotions? Or, in a more restricted enquiry, what are possible beginnings for variation in the subjective responses to architectural space?

At present it is proposed to accept a subjective response as it seems to be defined at a given moment in time, irrespective of definition of the given personality and given mood. Responses may then be obtained for a variety of situations in which a subject finds himself within a short interval of time.

In the nature of this discussion it is suggested that there is validity in presenting certain basic responses which appear to affect the spatial experience of the writer. Other writings of apparently similar responses will be given to illustrate these responses.

Given a spatial situation, the subject may choose to linger or leave. The space itself may suggest the response. Alternatively climatic conditions, social inferences or immediately preceding activities may suggest an emphasis on shelter, status, or a temporary ergonomic "necessity" for rest or exercise.

Pevsner (1963) described a visit to Amiens Cathedral.

> "The narrowness of the arches and the uniform shape of the piers do not seem to call for even a momentary change of direction. They accompany one on one's way. ... There is not time at first to stop and admire them. Yet in pressing forward, the transept halts us and diverts our eyes to the right and left. Here we stop, here we endeavour for the first time to take in the whole. In an Early Christian church nothing of this kind was provided, in a Romanesque church so much of it that movement went slowly from bay to bay, from compartment to compartment. At Amiens there is only one such halt, and it cannot be long. Again nave and aisles, now of the chancel, close round us, and we do not come to an ultimate rest until we have reached the apse and the ambulatory, gathering with splendid energy the parallel streams of east-bound energy and concentrating

them in a final soaring movement ...

> "This description is an attempt at analysing a spatial experience."[35]

Zevi (1957) summarized a similar spatial experience.

> "When we enter the end of a nave and find ourselves in a long vista of columns, we begin, almost under compulsion, to walk forward: the character of the space demands it. ... The space has suggested a movement."[36]

The position of a subject in space may determine a range of responses on a scale of dominance-command. In one situation the subject may feel dominated by the space, in another feelings of command may stem from his position in space. The arrangement of furniture in a room may give evidence of security against attack or may simply illustrate a desire to be in control. The position of the desk in the interview room, in its relation to the door and seating arrangements, may tend to place one individual in command, the other in submission. This is illustrated in Fig. 18.

Clouten (1967) illustrated an architect's

---

[35] N. Pevsner, An Outline of European Architecture (Harmondsworth: Penguin, 1963) 108-110.

[36] Zevi, Op. cit., 217.

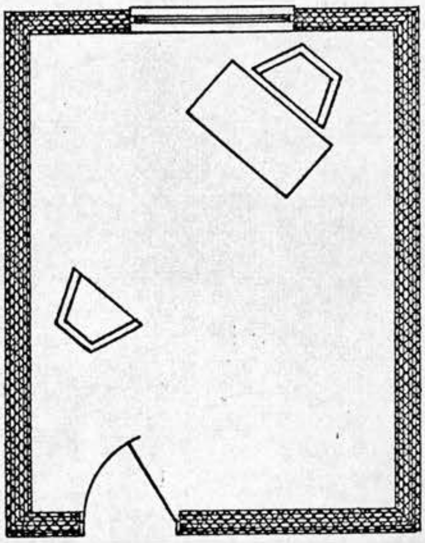
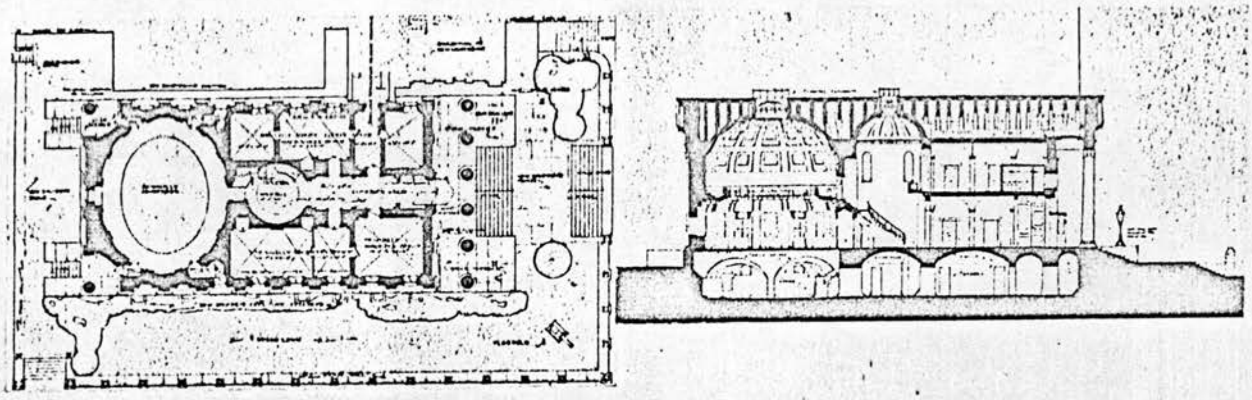
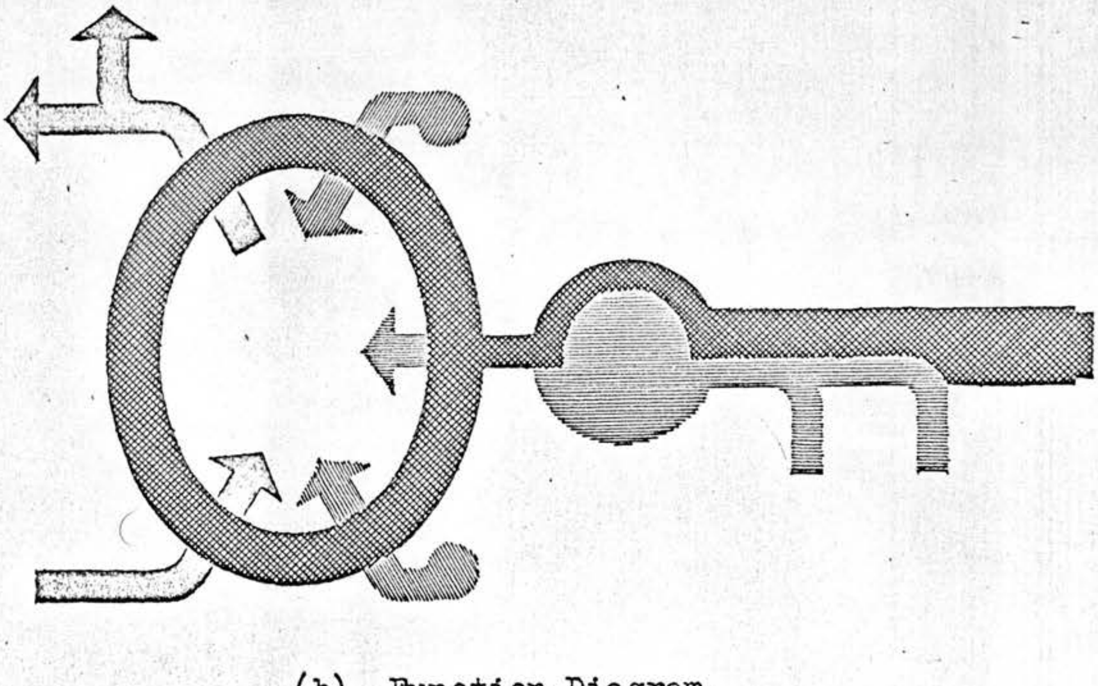


Fig. 18. Command-dominance. Determined by arrangement of furniture.

ability to design for function keeping in mind the nature of subjective responses. A function diagram of the Old Montgomery County Court House, Dayton, Ohio is given in Fig. 19. The public (black lines) entered the main hall and proceeded by way of the spiral stair to the courtroom gallery. The recorder and sheriff (horizontal lines) moved from their offices on the left at the ground floor to take up their positions at the entrance to the courtroom. The judge was located on the left side of the floor above and entered the courtroom by a private enclosed stair. The jury similarly entered on the right. The prisoner



(a) Plan, Section.



(b) Function Diagram.

Fig. 19. The Old Montgomery County Court House, Dayton, Ohio.

(grey lines) entered the courtroom from the jail located at the rear of the Court House. The gallows were conveniently located between the jail and the courtroom.

The function diagram indicates that the planning centred on the six doors to the courtroom. It indicates further that, on entering this space, each participant was located near the periphery of the space with no cross traffic. Without penetrating the centre of the space there could not be a feeling of command. The space was designed to be dominant.

The planning of a space and the position of a subject in the space may strongly influence subjective responses. In the Mediaeval piazza a response of dominance may depend on proximity to the church towers, Fig. 20. Zucker (1966) described a church tower in a particular geographic location and an historical context. The description, however, illustrates a response which may be aroused from a wide range of conditions.

> "The dark square tower of the Cathedral of Mecheln, visible for many miles over the flat fields of Flanders, is an uncompromizing, demanding, threatening sign of the Archbishop's

indisputable rule over the nameless peasants of the field."[37]

Michelis (1964) described a response of command dependent on spatial location.

"In circular halls ... man derives a great deal of pleasure from standing at the centre — particularly when it is crowned with a dome evocative of the heavenly vault — for he feels himself to be the hub and axis of the universe."[38]

A path is governed in direction and additionally may be governed in time. A point along a path may be important to the subject only in that it provides physical access from one position to another. The

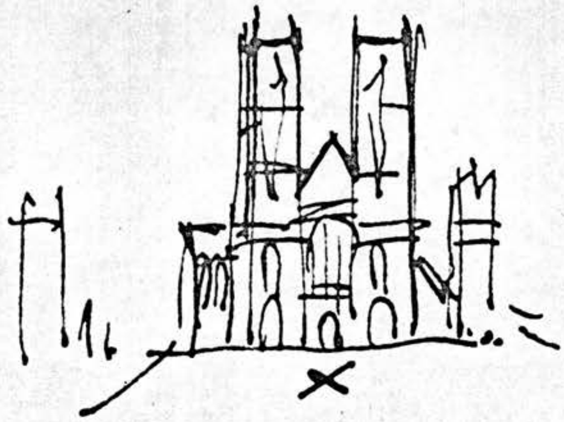


Fig. 20. Dominance.
Determined by proximity.

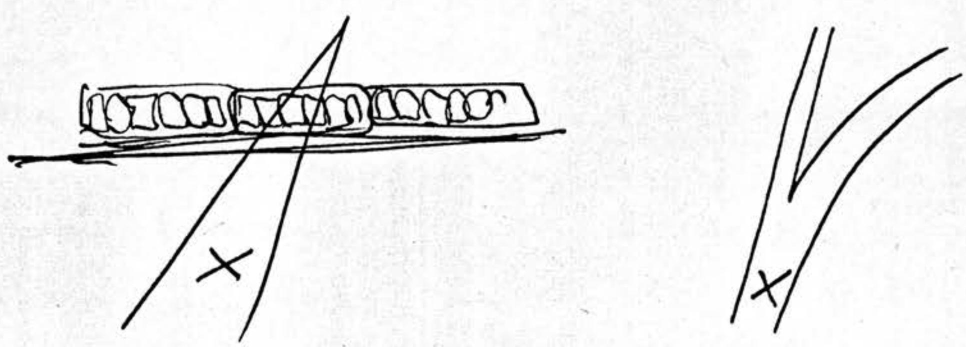
---

[37] W. M. Zucker, "Inside and Outside in Architecture: A Symposium," Journ. Aesth. & Art Crit., 25:1, (1966) 10.

[38] P. A. Michelis, "Reflections on Architecture," Journ. Aesth. & Art Crit., 23:1, (1964) 140.

spiral stair in the Old Montgomery County Court House dictates movement, Fig. 19. A survey of the experience of persons entering the Court House for the first time has shown that the spiral stair, as a three-dimensional expression of a path through space, is given preference to the two-dimensional expression of the lower doorway.

A barrier interrupts movement, a duality may or may not be resolved before movement has ceased, Fig. 21. As in a path, a barrier may be physical or psychological. An arrangement of forms may physically permit entry, but the possibility of a more secure or attractive alternative may alter the direction, speed or mode of travel, Fig. 22. The French mime, Marceau, vividly portrayed a "cage" as a psychological barrier by repeated reactions to an invisible definition of space.



(a) Barrier (b) Duality

Fig. 21. Interrupted Movement.

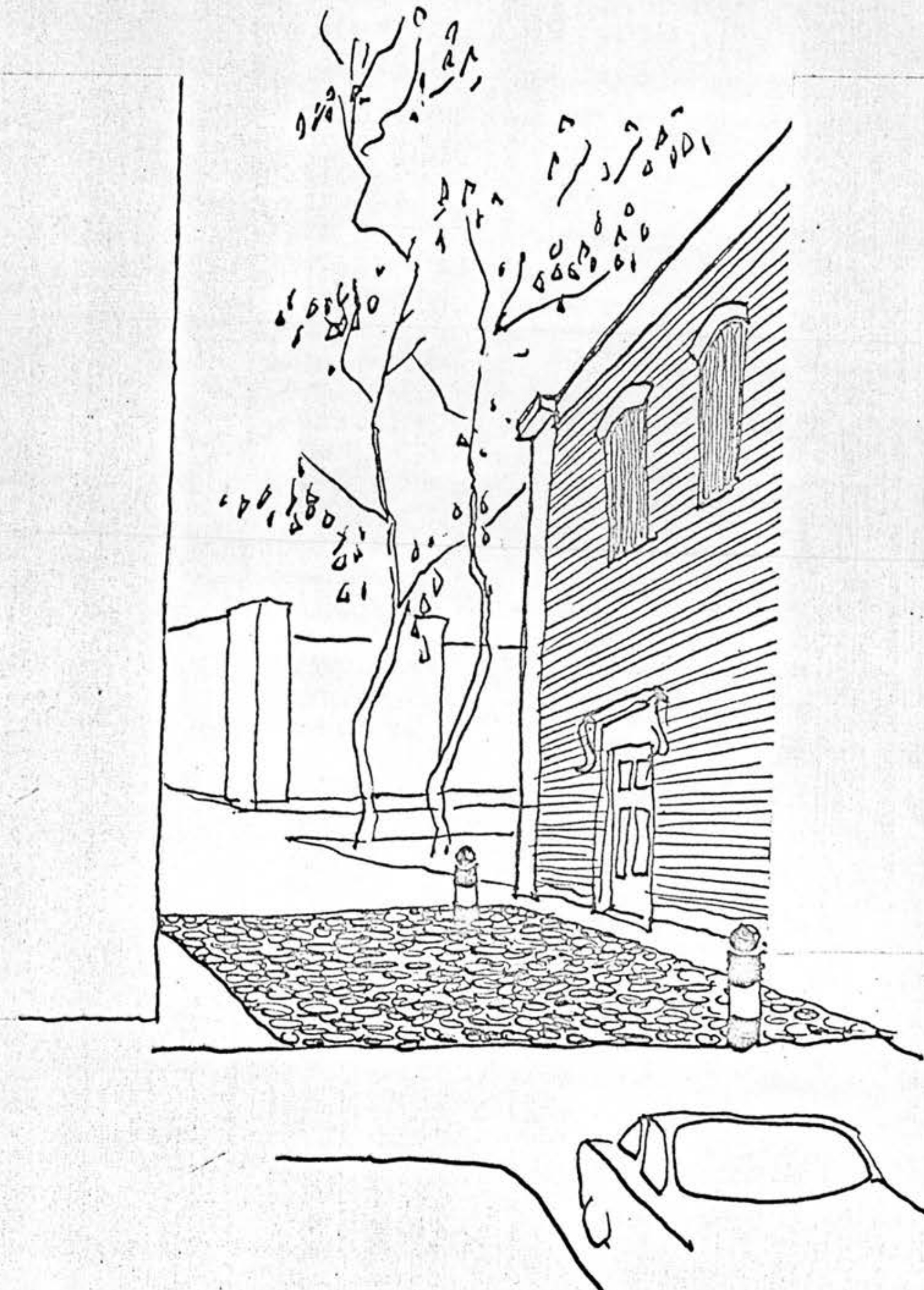


Fig. 22. Psychological Barrier.
(Adapted from Cullen)

Arnheim (1966) selected the barrier-passage terminology to illustrate that architectural design must locate itself somewhere on the scale of complete blockage and complete passage.

> "The impregnability of buildings spatially reflects an early conception of human existence; man surrounded by barriers and faced by closed entities which must be cracked if they are to be penetrated ...
>
> "We have found it necessary to interpret the combination of closed and open spaces as a dynamic interplay of barriers and passages."[39]

A path in one direction is often a barrier from another. The motorway has meaning as a path while travelling along it, but for the pedestrian trying to cross from home to neighbourhood shops this same motorway represents a barrier. The importance of location in space is again illustrated from the design of the Baker House M.I.T. dormitories on the bank of the Charles River, Boston. Aalto insisted that a view across the river was to be avoided. The undulating wall ensured that each window faced up or down the river. No longer a barrier, the river flowed from a position on one horizon to the Boston Harbour on the other. As a path it had acquired meaning.

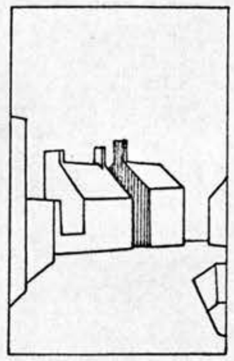
---

[39] Arnheim, <u>Op. cit.,</u> 10.

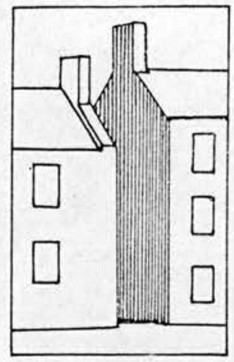
Three basic responses to architectural space, each of polarity, have been suggested as appropriate beginnings for a study of variation in subjective response. A static-dynamic polarity indicates a response to linger or move through a space, a dominance-command polarity reflects a subjective feeling of position within a space, and a path-barrier polarity relates to anticipated movement.

In an attempt to substantiate that the cited responses would have meaning to a group of subjects, two feasibility studies were carried out. The first took place within a spatial sequence in the field. Results were limited to introspective analyses by a small number of subjects at the time of the experiment. The second feasibility study was carried out in the laboratory using stereoscopic displays of space. In this case questionaires were given to groups of subjects.

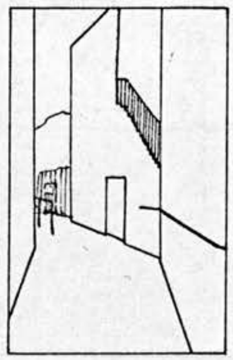
On the several visits to Pittenweem, Fife, the sequence "Cove Wynd" from the harbour to High Street has given particular interest to the writer. The sequence is illustrated in Fig. 23 from positions numbered on the plan, Fig. 24. High Street is approximately one hundred feet above the harbour level.



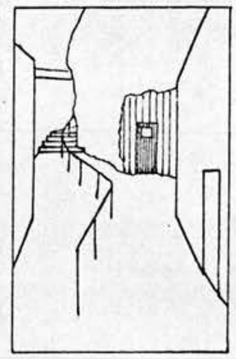
(a) From Harbour.



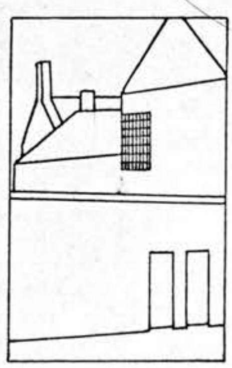
(b) Cove Wynd.



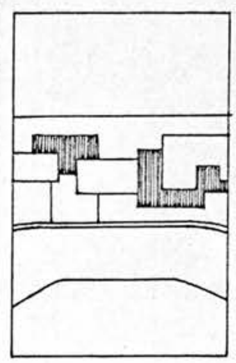
(c) Entering Cove Wynd.



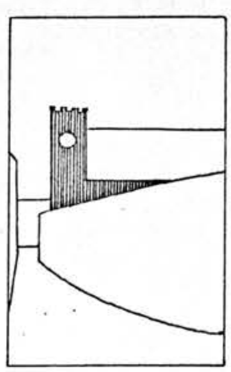
(d) Towards Position 1.



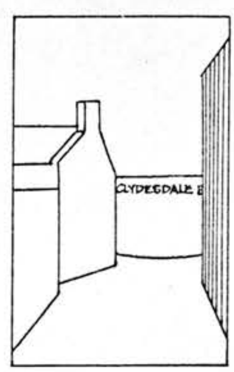
(e) View from Position 1.



(f) View from Position 2.



(g) View from Position 2a.



(h) Towards Position 3.

Fig. 23. Cove Wynd, Pittenweem, Fife.

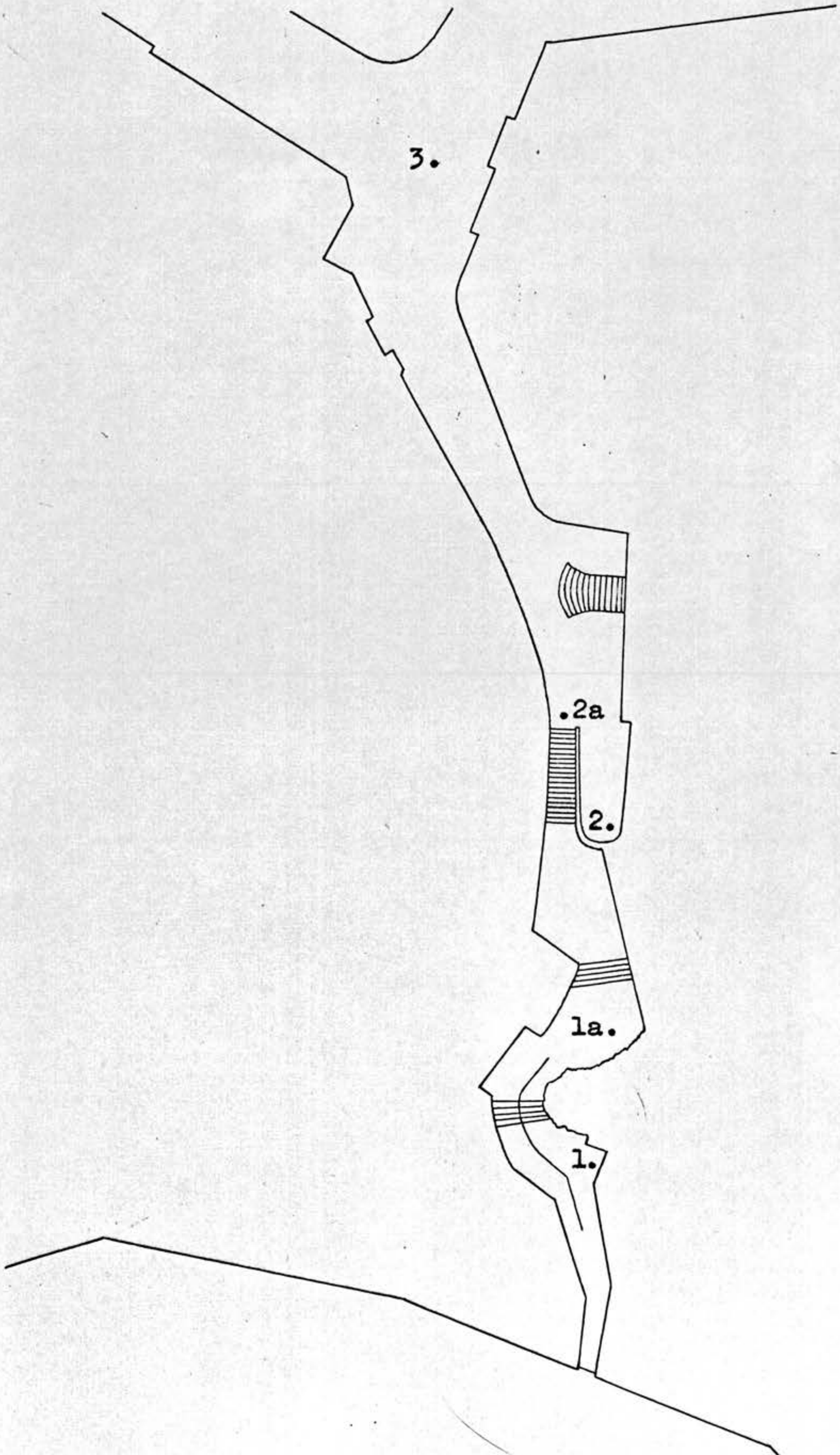


Fig. 24. Cove Wynd, Pittenweem, Fife.
Plan.

Seven subjects were taken to Pittenweem. None of the subjects were familiar with Cove Wynd, six had not visited Pittenweem prior to the time of the experiment. Subjects A and B were architects, C an architectural student, D a surgeon, and E a physiotherapist. These five subjects were independently briefed to analyse their responses on initial contact with the spatial sequence. Their responses, variation in response and the positions where variations occurred were described to the writer immediately following the experience of each subject. Subject F, an architect and post-graduate student, was briefed to analyse the sequence and to mark positions and directions for stereoscopic photography in an attempt to record the essence of the spatial sequence. Subject G was an architectural student. No brief was given to this subject who was under the impression that he was walking to another sequence for subjective analysis. The subject assumed that a brief would be given upon arrival at the commencement of the sequence. A person, not known to the subject, followed him through Cove Wynd and noted positions of reduction or suspension of movement and of changes in direction of viewing. Upon arrival at High Street the subject was met and questioned by the writer as to his responses along Cove Wynd. The subject returned to the harbour by another route and again ascended Cove Wynd. The seven subjects and the writer later discussed the spatial sequence.

The experiences of the subjects indicated to the writer that there were three positions along Cove Wynd where movement was likely to cease. Reports from all subjects, including the observation of subject G, were in agreement that a first position of suspended movement occurred at the corner marked 1 in Fig. 24. At this position there is a sudden profusion of visual interest. The natural rock formation, in several instances sunlit, and the door to the cave of St. Fillan were important visually, Fig. 23(d). A notice on the door was read by six subjects. From this position the colours and textures of the unroofed adjacent house and the chimneys beyond were visible for the first time.

Subjects C and D temporarily suspended movement, and E walked more slowly, near position 1a (Fig. 24) in order to determine if there was any evidence of the cave from the other side of the rock outcrop.

Subjects A, B, C and F did not stop at the top of the long flight of stairs, position 2a, but turned aside to position 2. The view over the red roofs to the harbour from this position is shown in Fig. 23(f). Subject D described a short ergonomic rest at position

2a, with a backward glance. But the forward view of St. John's Church beyond the retaining wall, Fig. 23(g), led him to continue along the path. Subject E described a point of rest at position 2a with extensive viewing of lower Cove Wynd and the harbour. This subject reported that there was indecision in proceeding to position 2. An automobile was parked in the space between position 2 and 2a at the time but pedestrian entry was not physically restricted. Subjects D, E and G reported that, while ascending the stairs, they imagined a fine view at the top of the stair and anticipated a feeling similar to that described as command by the writer. However the view of the church above, first seen from this position, led to the non-realization of this anticipated response. Subjects A and B, on the other hand, considered that their feelings changed markedly from the experience along the path to that at position 2. All subjects, particularly E and G, described feelings similar to dominance while ascending lower Cove Wynd. The narrowness of the path, changes in level, and alterations in direction due to the rock outcrop were considered important until position 2a. Then the church tower and the stone retaining wall became important.

All subjects described a stationary point at the junction of Cove Wynd and High Street. This was attributed to the proximity of St. John's Church, the details of the facade, and the vistas along High Street in the two directions. The duality in the main road was seen to exist while approaching position 3 but this was resolved once the commercial importance of High Street to the left was established. Subjects B, C and G reported that the Clydesdale Bank at the corner of High Street, Fig. 23(h), superseded the church as the centre of interest during the last fifty feet of Cove Wynd. All subjects agreed that the spatial sequence naturally ended at the position 3. Subject D entered the church, two subjects returned to the harbour, and four made their way to the shops in High Street.

The second feasibility study consisted of the projection of six stereopairs. These are illustrated in Fig. 25(A)-(F). Two questionaires were prepared.

The first questionaire listed quotations from other writers which appeared to describe responses of lingering-movement, dominance-command, and path-barrier. In this way the subjects were unaware of the limited terminology given by the writer. Each subject was asked to compare his response from each display with the response that was suggested from the

Display A.

Display B.

Fig. 25(A)-(F) Displays for Subjective Response Questionaires. (Right Images of Stereoscopic Displays)

Display C.

Display D.

Fig. 25(A)-(F) Displays for Subjective Response Questionaires. (Right Images of Stereoscopic Displays)

Display E.

Display F.

Fig. 25(A)-(F) Displays for Subjective Response Questionaires. (Right Images of Stereoscopic Displays)

quotations applying to other contexts.[40] The questionaire is given in Table V.

The second questionaire dealt with the same polarities written by the writer as a series of questions. This questionaire is given in Table VI.

The questionaires were given to separate groups of fifty subjects. In each group there were five architects and twenty-five architectural students. The remaining twenty subjects in each group were non-professional or from professions other than architecture.

Subjective responses to the projected stereoscopic displays are given in Table VII. In this table the figures at the top of each division refer to the Quotation form of questionaire. Those on the lower edge of the division refer to the Question form.

In Display A (Cathedral, Salisbury) the results from the quotation form of questionaire

---

[40] References to quotations in the order in which they appear in the first questionaire:
Arnheim, Op. cit., 6.
Hall, Op. cit., 166.
Zucker, Op. cit., 11.
Mechelis, Op. cit., 140.
Arnheim, Op. cit., 6.
Ibid., 10.

Table V. Subjective Response Questionaire.
Quotation Form.

"To the South Boston villagers, the street did not represent just a route through the area but was a family living room taking the place of a piazza."

"Space ... is an invitation to transit, traversed by actual and potential trajectories ... "

There will be six displays projected. Each will be projected for 30 seconds. Following each display, please indicate by X whether the display appears to be more similar to "a family living room taking the place of a piazza" or whether it rather appears to offer "an invitation to transit, traversed by actual and potential trajectories".

DISPLAY	"a family living room taking the place of a piazza"	"an invitation to transit, traversed by actual and potential trajectories"	Neither
A			
B			
C			
D			
E			
F			

Table V. Continued.

"The dark square tower of the Cathedral of Mecheln, visible for many miles over the flat fields of Flanders, is an uncompromising, demanding, threatening sign of the Archbishop's indisputable rule over the nameless peasants of the field."

"In circular halls ... man derives a great deal of pleasure from standing at the centre — particularly when it is crowned with a dome evocative of the heavenly vault — for he feels himself to be the hub and axis of the universe."

The six displays will again be projected for 30 seconds. Following each display, please indicate whether the surroundings appear to be "uncompromising, demanding, threatening" to you or whether you appear to be "the hub and axis" of the surroundings.

DISPLAY	"uncompromising, demanding, threatening"	"the hub and axis"	Neither
A			
B			
C			
D			
E			
F			

Table V. Continued.

"Architectural dynamics acquires meaning only through the channelling of direction ..."

"The impregnability of buildings spatially reflects an early conception of human existence: man surrounded by barriers and faced by closed entities which must be cracked if they are to be penetrated ..."

The six displays will again be projected for 30 seconds. Following each display, please indicate whether the display seems to indicate "the channelling of direction" or whether it appears to act as a "barrier" to movement.

DISPLAY	"the channelling of direction"	"barrier"	Neither
A			
B			
C			
D			
E			
F			

Table VI. Subjective Response Questionaire.
Question Form.

In each display, imagine yourself to be at the position of the camera during photography.

	DISPLAY A	B	C	D	E	F
Does the display suggest that you linger in the space ?						
Does the display suggest that you move through the space ?						
Both questions are inappropriate.						

	A	B	C	D	E	F
Do you feel that the space is dominating you ?						
Do you feel that you are in command of the space ?						
Both questions are inappropriate.						

	A	B	C	D	E	F
Does the display show you a path through space ?						
Does the display present a barrier to your movement ?						
Both questions are inappropriate.						

Table VII. Subjective Responses to Questionaires.

Quotation form of Questionaire (upper left of each cell) / Question form of Questionaire (lower right of each cell)

DISPLAY

	A	B	C	D	E	F
Linger.	3 / 19	22 / 45	2 / 8	/ 3	3 / 5	31 / 47
Move through.	41 / 31	18 /	40 / 41	49 / 46	34 / 43	14 / 3
Inapprop.	6 /	10 / 5	8 / 1	1 / 1	13 / 2	5 /

	A	B	C	D	E	F
Dominating.	32 / 47	23 / 31	14 / 7	1 / 9	39 / 45	11 / 18
Command.	8 / 1	15 / 16	36 / 43	42 / 39	7 / 1	32 / 30
Inapprop.	10 / 2	12 / 3	/	7 / 2	4 / 4	7 / 2

	A	B	C	D	E	F
Path.	39 / 31	17 / 6	26 / 27	48 / 50	8 / 39	32 / 47
Barrier.	5 / 18	26 / 41	16 / 22	/	33 / 8	6 / 1
Inapprop.	6 / 1	7 / 3	8 / 1	2 /	9 / 3	12 / 2

indicated movement and a path. The question form emphasized dominance.

The question form provided a marked response to linger in Display B (Fountain, St. Louis). The proximity to the water, as a barrier, was emphasized to a greater extent in responses to the question form.

Movement through space was important in Display C (Monte Alban, Mexico). These responses had not been largely based on the provision of a physical path from the upper platform, for responses to this latter classification were considerably fewer than responses to move through the space. The elevated viewpoint would account for responses of command.

In Display D (University of Jyvaskyla, Finland) there are marked responses for movement and path. The display seems to have been accepted by the subjects as an illustration of invited movement. From the information given in the display two paths are presented, but it may be assumed that most subjects accepted the position of photography as a point of suspended movement on one path. Instead of a duality seen by arrival at the position in space from a third path, the two paths were seen to be in reality a single path connecting exterior space with an elevated interior space. Movement was taking place along a meaningful path. The responses of command, particularly those from the quotation of a central location in space, further substantiate this view. The figures in Table VII then suggest considerable agreement in meaning derived from this stereoscopic display.

The question form of questionaire emphasized movement and dominance in Display E (Stonehenge, England). A reversal is indicated in path-barrier responses to the question and quotation form. It is suggested that the reference to the historical importance of barriers in the quotation was associated with the familiar historic location at Stonehenge.

A response to linger in the space, but with the acceptance of a path, is indicated in Display F (Market Hall, Perigord, France). This provides an interesting comparison with Display D (University of Jyvaskyla, Finland) where movement and path were linked. It may suggest that the path at the university was seen to provide a means to leave the space whereas in the market hall the path provides a means to experience the space.

It is seen from Table VII that the quotation form of questionaire generally led to an increased use of inappropriate classifications. This may illustrate the difficulties in approaching polarity using quotations. In some instances the questions and quotations have not scaled similar polarities. Social, economic, historical and geographical implications were suggested by the quotations, particularly in the quotations on lingering, dominance and barrier. These implications have widened the inclusion of subjective associative experiences, and this has generally tended to reduce the intensity of responses to the suggested classifications. It is concluded from the results in Table VII that a limited terminology has been more acceptable to subjects for this classification of subjective responses than freedom to individually interpret quotations from other writers.

CLASSIFICATION

VIII. CLASSIFICATION OF SPATIAL SEQUENCES

In Chapter IV it was suggested that isolation of a spatial sequence was dependent on points in the sequence where individual experiences appeared to begin and end. A spatial sequence would then be analysed in three parts — an initial experience, a transition experience, and a concluding experience that would be fundamentally different from the initial and transition experience.

Cullen (1961) emphasized the importance of a sense of identity from contrasting elements in townscape design.

> "Arising out of this sense of identity or sympathy with the environment, this feeling of a person in street or square that he is in IT or entering IT or leaving IT, we discover that no sooner do we postulate a HERE than automatically we must create a THERE."[41]

The supervisor for this study, Mr. P. F. Crofts, Department of Architecture Edinburgh University, has

---

[41] G. Cullen, Townscape (London: Architectural Press, 1961) 12.

suggested that a space may be identified as a subjective classification of threshold, experience and exit, and has referred to this as the "Threshold Theory". The writer has applied this terminology to the classification of spatial sequences. This is stated in the following postulate:

THAT the "Threshold Theory" is a valid means of analysing spatial sequences. THAT a spatial sequence consists of points of threshold, experience and exit. THAT these points, when isolated and recorded in the field and used as stereoscopic displays in the laboratory, can represent the spatial sequence.

The three elements of threshold, experience and exit define a complete spatial sequence. Individual experience of a spatial sequence varies largely from additions to the minimal experience from threshold to exit. Stimulation is increased by aesthetic "obstacles" which overrule the shortest possible transit time — delays that are not required by physiological, ergonomic or other functional considerations. On the other hand, the close proximity of one experience to the preceding may heighten the aesthetic appeal, particularly on the first encounter. Drama is then added to the spatial sequence.

Definition of a path through space may be provided by physical boundaries. The spatial sequence at Cove Wynd, Pittenweem, has been described in Chapter VII.

A subject may be led to experience a space or series of spaces in a designer's predetermined order and manner. Baroque architecture provides many examples of this. The writer has selected an example from contemporary architecture.

The architect of the Sydney Opera House, Utzon (1959) has been concerned with a dramatic moment — the initial experience of the spatial sequences in that building.

> "The building as a whole has only to perform one purpose. Its goal is to prepare the audience for a festival."[42]

With great sensitivity Utzon has designed a series of spatial sequences from the harbourside to the vaulted halls. There is a threshold from the openness of the harbour to the low ceiling height of the foyer, the experience of the foyer, and the exit to the stair canopy. Then there is the threshold to the great height of a vaulted roof structure, experience within, and the exit to the open space

---

[42] J. Utzon, "Ideas of a Danish Architect: Platforms and Plateaus," Zodiac, 10, (Milan, 1959) 112.

between the two groups of shell vaults. There is the threshold to the auditorium, experience, and exit to the openness of the harbour.

The writer visited the Sydney Opera House project, from July to September 1967, to photograph these spatial sequences. The building at that time presented a contrast of fully defined spaces with spaces that will not be kept in their present state for acoustic and other considerations.

The design of the architect has given definition for a subject's path and a basis for photography. The writer selected the location of the point of threshold, experience and exit for each spatial sequence on the site. From the first point of threshold a stereoscopic slide was photographed. A stereoscopic motion picture was commenced at this point and continued while the camera was moved to the selected position of experience. A stereoscopic slide was taken at this point, then the motion picture continued to the position of exit. Another stereoscopic slide was photographed and the procedure continued in this way so that conditions of light and composition were kept uniform for both methods of photographic recording. The series of stereoscopic slides were photographed vertically and mounted so that, upon projection, they would be similar in format to the frames contained within the stereoscopic motion picture photographed from the same position.

Twelve consecutive stereoscopic slides were used as displays for the study of subjective responses and eye fixations. The first spatial sequence represented in this series of slides was the threshold, experience and exit of the stage area of the Minor Hall. This sequence is shown in Displays 2 to 5. The classification of the twelve displays is given in Table VIII. The positions of photography are indicated on the plan of the Sydney Opera House, Fig. 26. The displays are illustrated later in Fig. 40.

Table VIII. Classification.
Displays of Spatial Sequences,
The Sydney Opera House.

DISPLAY	Classification	Description
1	Experience	between shell vaults.
2	Threshold	to stage area of Minor Hall.
3	Experience	stage area — Inclined view.
4	Experience	stage area.
5	Exit	from stage.
6	Threshold	stairs.
7	Experience	harbour.
8	Exit	shell vault of Minor Hall.
9	Experience	shell vaults — Inclined.
10	Experience	between shell vaults.
11	Threshold	to shell vault of Major Hall.
12	Experience	Major Hall.

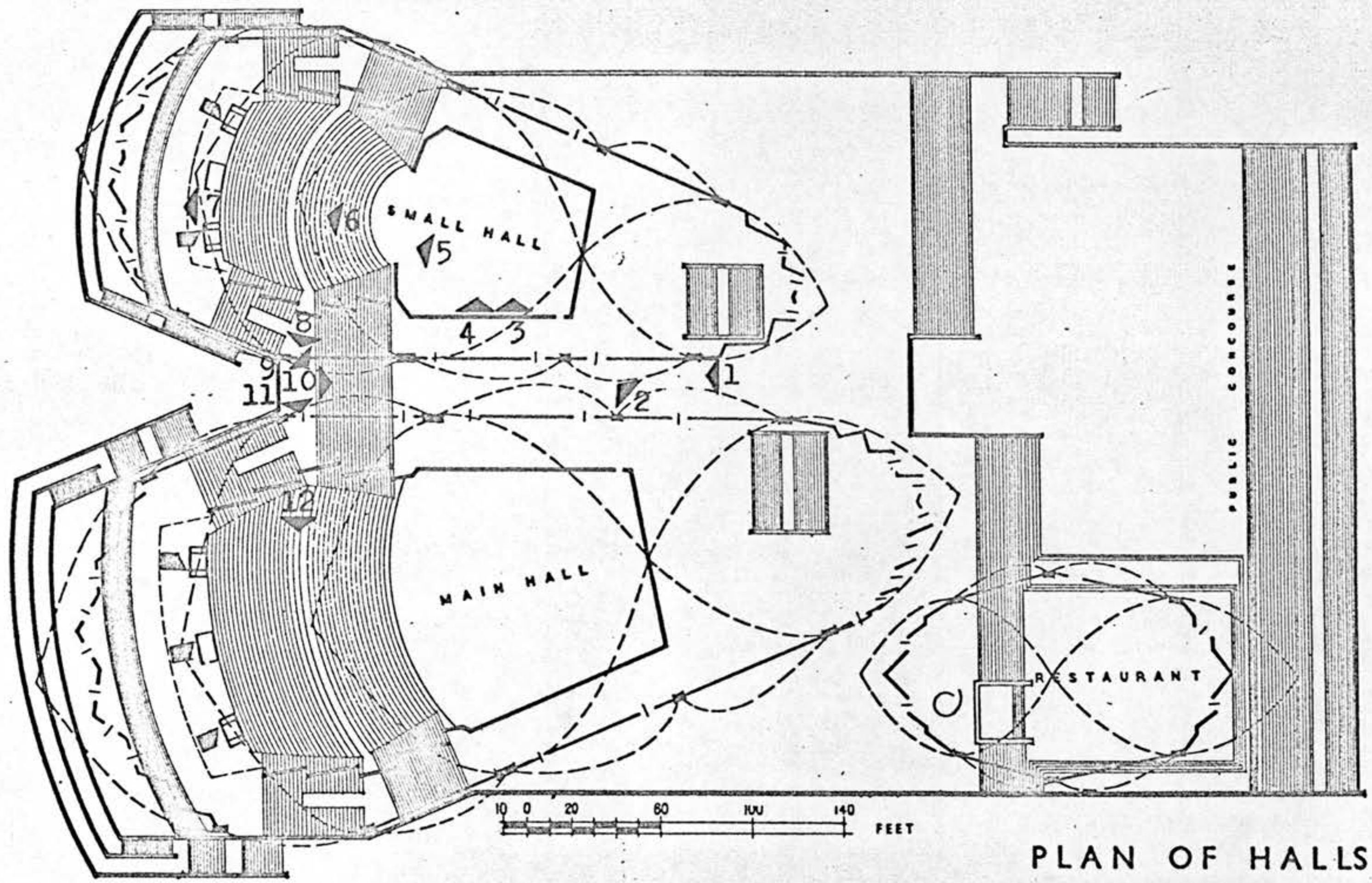


Fig. 26. The Sydney Opera House.

IX. CLASSIFICATION OF PERSONALITY

> "We are living, behaving systems surrounded by a skin which protudes into space-time in an engaging variety of patterns. The skin is the boundary which separates us from the environment."[43]

Miller (1959) emphasized that measurement of the environment remains entirely different and unrelated to dimensions of personality assessment. As an engineer, Miller is able to list the units of the centimetre-gramme-second system and its derivatives, and attribute meaning to measurements taken from the environment. Upon crossing the boundary of the skin there is a completely different system of measurement.

Buswell (1935) in his book "How People Look at Pictures: A Study of the Psychology of Perception in Art" refused to proceed beyond the boundary of environment and subject.

---

[43] J. C. Miller, "Future Impact of Psychological Theory on Personality Assessments." See B. M. Bass and I. A. Berg, Ed., Objective Approaches to Personality Assessment (New Jersey: Van Nostrand, 1959) 204.

> "If the mental experiences which occur as a subject looks at a picture could be known, it would then be possible to correlate them directly with the objective record of the fixations of the eyes. However, any record of the content of the mind must, in the very nature of the case, depend on introspection from memory after the picture has been seen. The dangers of misrepresenting such subjective evidence are so great that the writer has chosen to make no attempt to deal with subjective accounts of mental experiences while looking at pictures."[44]

Architects have shown an increasing interest in the work of the psychologist, especially in the development of subjective measurement. The concern has followed the psychologist, questioning the entire experience of human perception from the response of the eye to the scaling of subjective responses.

Movements of the eyes are significant to the writer in that they are symptoms of the perceptual processes. But the perceptual processes are defined only in terms of an individual and his response to an environment. The individual is a resultant of heredity and conditioning, of a family and cultural background modified by training and interests. This constantly changing resultant, personality, determines behaviour for a given moment in time. It is customary to divide the more static patterns of

---

[44]G. T. Buswell, How People Look at Pictures: A Study of the Psychology of Perception in Art (Illinois: Univ. of Chicago, 1935) 85.

individual behaviour from the fluctuations that occur above and below these more normal patterns. Personality is then defined as that which determines behaviour in a defined situation and a defined mood.

The observation of more static patterns of behaviour early suggested trait names. Greek philosophy understood man as a microcosmic reflection of nature, and as such he must express the properties of the cosmos. The cosmic elements, their properties, corresponding humors and temperaments are given in Table IX.

Allport (1938) proposed a psychograph, a personality profile in graph form, to demonstrate the

Table IX. Cosmic Elements and Temperaments. (From Allport)

Cosmic Elements	Properties	Corresponding Humors	Corresponding Temperaments
Empedocles cir. 450 B.C.		Hippocrates cir. 400 B.C.	
Air	warm, moist	blood	sanguine
Earth	cold, dry	black bile	melancholic
Fire	warm, dry	yellow bile	choleric
Water	cold, moist	phlegm	phlegmatic

magnitude of common traits for an individual subject. This is given in Fig. 27. It is of interest that temperament is analysed in the first place by emotional range, and in the second by emotional intensity.

> "A person with a wide 'affective spread' is one who reacts emotionally to a broad range of objects and situations. The person of narrow emotional spread responds infrequently in an emotional manner ...
>
> "The characteristic _intensity_ of feeling seems a different dimension altogether from emotional _spread_. Here is a question, not of how many situations arouse emotional response, but rather of the average degree of the response.
>
> "If the profile drawn upon the psychograph stands well above the average on both the breadth and strength of emotionality, the result suggests the ancient portrait of the _choleric_ type; if the range is broad, but the intensity low, the _sanguine_ type; if the range is narrow but the response intense, the _melancholic_ type; if the emotional life is both narrow and weak, the _phlegmatic_ type."[45]

Allport however found over 3000 words for describing personality. Agreement among psychologists for a restricted list of trait names has proved ineffectual.

---

[45] G. W. Allport, _Personality, A Psychological Interpretation_ (London: Constable, 1938) 408.

UNDERLYING PSYCHOBIOLOGICAL FACTORS							COMMON TRAITS OF PERSONALITY													
PHYSIQUE			INTELLIGENCE		TEMPERAMENT		EXPRESSIVE			ATTITUDINAL										
											DIRECTED TOWARD SELF		DIRECTED TOWARDS OTHERS			DIRECTED TOWARDS VALUES				
SYMMETRY	HEALTH	VITALITY	ABSTRACT (VERBAL)	MECHAN-ICAL (PRACTI-CAL)	BROAD EMOTIONS	STRONG EMOTIONS	ASCEND-ANCE	EXPAN-SION	PERSIST-ENCE	EXTRO-VERSION	SELF-OBJECTIFI-CATION	SELF-ASSUR-ANCE	GREGAR-IOUSNESS	ALTRUISM (SOCIAL-IZATION)	SOCIAL INTELLI-GENCE (TACT)	THEORET-ICAL	ECONOMIC	AESTHETIC	POLITICAL	RELIGIOUS
DEFORMITY	ILL-HEALTH	LOW VITALITY	LOW ABSTRACT INTELLI-GENCE	LOW MECHANICAL INTELLI-GENCE	NARROW EMOTIONS	WEAK EMOTIONS	SUB-MISSION	RECLUSION	VACILLA-TION	INTRO-VERSION	SELF-DECEPTION	SELF-DISTRUST	SOLITARI-NESS	SELF-SEEKING (UNSOCIAL-IZED BEHAVIOR)	LOW SOCIAL INTELLI-GENCE (TACTLESS-NESS)	NON-THEORET-ICAL	NON-ECONOMIC	NON-AESTHETIC	NON-POLITICAL	NON-RELIGIOUS

Fig. 27. Psychograph.
(From Allport)

> "Any investigator with an interest in *any* common segment of human behaviour, may, if he chooses, propose it as a common trait. There is scarcely any limit to the process."[46]

Controversies in personality trait identification were appropriately curtailed with the application of the statistical methods of factor analysis to the study of personality.

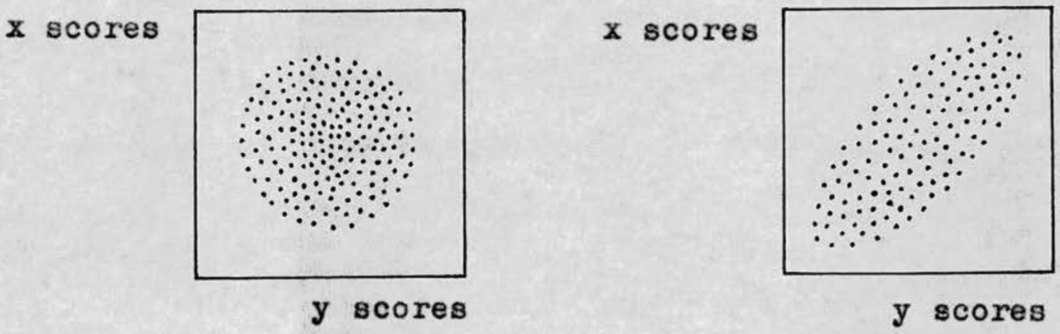
The factor analysis of personality begins with the assumption that there are natural, unitary structures in personality. These structures determine patterns of response. By correlating manifestations that appear and disappear together, single structures are isolated.

In Fig. 28 each point represents a subject's score in two dimensions. A random relation is shown in (a). A positive correlation of the two dimensions is given in (b).

The Bravais-Pearson correlation coefficient provides a measure of the tendency for two dimensions to "go together". A correlation coefficient of +1.0 would be perfect correlation, Fig. 29(a); -1.0 a perfect inverse correlation (b).

---

[46] Ibid., 401.



(a) Random. (b) Correlation positive.

Fig. 28. Correspondences of Measurement.
(From Cattell)

Spearman, Thurstone (1931) and others developed the mathematical technique of loading factors which had been recognized to occur in clusters. Eysenck (1940) and Cattell (1943, 1945) applied the methods of factor analysis to personality measurement.

Subjective behaviour may be observed in actual every-day situations. Such "L-data" or life record

(a) +1.0 (b) -1.0

Fig. 29. Correlation.
(From Cattell)

information is frequently obtained from ratings made by observers on the frequency and intensity of specific behaviour seen in subjects.

> "Under ideal conditions, notably with
> (a) at least ten raters for each person,
> (b) ranking one trait at a time,
> (c) definition of the trait in exact behavioural terms,
> (d) visibility of ratee over most of the day,
> it is possible ... to obtain quite high reliability.
>
> "The reliability of interview evaluations by two different interviewers commonly runs no better than +0.3 or +0.4."[47]

A subject may provide information from self-observation and introspection recorded in answer to questionaires. Such "Q-data" is liable to distortion by delusions regarding self or an intention to be untruthful. The questionaire is objective only in the method of scoring; for this reason it is termed conspective.

There is a great deal of validity in objective testing. The subject is placed in a miniature situation and his responses are measured by changes in objective factors such as fluency, visual preference or electrical skin resistance.

---

[47] R. B. Cattell, The Scientific Analysis of Personality (Harmondsworth: Penguin, 1965) 137, 88.

> "His cooperation is required to the extent that he agrees to be tested, but the objectivity in this type of test may be defined by the criterion that the subject does not know on what aspect of his behaviour he is really being evaluated."[48]

Objective tests demand the psychologist's skill in administration, ingenuity in experimental design and considerable apparatus. Although these are advantages in that "T-data" may provide high reliability, objective tests have until recently been used solely as special purpose tests unrelated to wider aspects of personality structure. Difficulties in discarding tests that are not truly objective, and the administrative time of those that are objective, has retarded the acceptance of this type of personality test for the range of behavioural responses. The Objective-Analytic Personality Battery by Cattell (1955) applied loadings from factor analysis to the individual items in the test battery.

The most widely used personality test today is the Sixteen Personality Factor Questionaire. Cattell and Eber (1957) first introduced the 16 P.F. questionaire Forms A and B to North America. Since this time several translations in other languages have been provided and further tests issued for lower

---

[48]Ibid., 104.

age and less educated groups in western populations. The wide acceptance of the test has substantiated the claim made by Cattell and Eber (1957).

> "The 16 P.F. is the psychologist's answer, in the questionaire realm, to the demand for a test giving fullest information in the shortest time about most personality traits. It ... sets out to cover planfully and precisely all the main dimensions along which people can differ, according to basic factor analytic research.
>
> "Although innumerable questionaires and inventories have been published in the last thirty years, only one or two have been well founded on factor analytic research showing that separate traits or dimensions of personality which they claim to measure are real, functionally unitary, and psychologically significant dimensions. The present questionaire meets a long-standing demand for a personality-measuring instrument properly validated with respect to primary personality factors that are rooted in general psychological research."[49]

The vocabulary of Forms A and B is similar to that of the daily newspaper. These forms are suitable for group or individual use in all but the most unskilled and least educated groups of adult population. A Form C is designed for the latter population groups. In Forms A and B three alternative answers are provided to each of the 187

---

[49] R. B. Cattell, Handbook for the Sixteen Personality Factor Questionaire, Forms A, B and C (Illinois: Inst. of Personality & Ability Testing, 1957) 1, 2.

items. For a maximum score on each factor there is an equal number of positive and negative answers required. The items in the questionaires have been arranged so that responses for one factor do not occur together. On the other hand a pattern is achieved on the answer sheet which offers maximum convenience in scoring.

The symbols A, B, C, E, F, G, H, I, L, M, N, O, Q_1, Q_2, Q_3 and Q_4 have been given to the sixteen factors, representing roughly diminishing contribution to behavioural variance. Each dimension is independent of any other so that a subject may combine any score on one factor with any score on others.

Cattell (1957) has shown that questionaires have most valid application with students or cooperative anonymous subjects under conditions of research. In the use of the 16 P.F. questionaire Cattell suggested that non-cooperation of a subject was more critical in terms of validity than ulterior motivation.

> "The majority of questions in the 16 P.F. are indirect, asking about interests which the subject would not necessarily perceive to be related to the trait in question. ... Moreover,

in the 16 P.F. we do not interpret the factors from the nature of the subject's statements about himself, but from the known correlations between these "mental interiors" as found in questionaire factors and the factors established in behaviour.

"The questions are not questions the answers to which we accepted at face value as descriptions of behaviour. Indeed, commonly, they are questions quite oblique in meaning which have been discovered to correlate with the factor.

"In a majority of factors, e.g. A, E, F, I, M, N, Q_1, one pole does not seem to be regarded by most people as any more morally or esthetically desirable than the other, while in C, G, L, O, Q_3 and Q_4, in which an attempt to represent "a desirable character" might be expected to operate, no systematic motivational distortion has yet been experimentally found."[50]

A bipolar description of the sixteen factors is given in Table X.

Given this range of personality factors it is possible to combine and load independent factors to measure specific performances. For example, from research by Drevdahl (1958), Jones (1963), Cattell (1963) and others, a weighting of personality factors has been formulated to estimate general creativity. This is given in Table XI.

In the binocular viewing of spatial sequences

---

[50] Ibid., 3, 7, 6.

Table X. Bipolar Description of Personality Factors.
The 16 P.F. Questionaire.

Factor		Title	Description
A	+	Affectothymia	good natured, easy-going, emotionally expressive
	-	Sizothymia	detached, critical, emotionally inexpressive
B	+	Higher scholastic	intelligent, quick to grasp ideas
	-	Lower scholastic	dull, slow to learn and grasp ideas
C	+	Higher ego strength	emotionally stable, realistic
	-	Lower ego strength	inability to control emotions, changeable
E	+	Dominance	assertive, self-assured, independent-minded
	-	Submissiveness	accommodating, conforming, retiring
F	+	Surgency	energetic, enthusiastic, cheerful
	-	Desurgency	restrained, concerned, taciturn, introspective
G	+	Higher super ego strength	conscientious, responsible, planful
	-	Lower super ego strength	unsteady in purpose, expedient
H	+	Parmia	venturesome, spontaneous, uninhibited, responsive
	-	Threctia	shy, restrained, feelings of inferiority
I	+	Premsia	dependent, sensitive, subjective, artistic
	-	Harria	self-defiant, independent, feelings overruled

Table X. Continued.

Factor		Title	Description
L	+	Protension	self-opinionated, intense subjectivity
	-	Alaxia	adaptable, uncompetitive, free of jealousy
M	+	Autia	imaginative, unconventional, creative
	-	Praxernia	practical, conventional, concerned over detail
N	+	Shrewdness	shrewd, penetrating, full of insight
	-	Artlessness	forthright, unsophisticated, sentimental
O	+	Guilt proneness	apprehensive, sensitive, easily upset, moody
	-	Untroubled adequacy	placid, self-assured, confident, insensitive
Q_1	+	Radicalism	experimenting, critical, liberal, analytical
	-	Conservatism	conservative, tolerant, respecting established ideas
Q_2	+	Self-sufficiency	resourceful, prefers own decisions, early developers
	-	Group adherence	depends on social approval and admiration
Q_3	+	High self-concept control	socially precise, regard for social reputation
	-	Low integration	undisciplined self-conflict, careless of protocol
Q_4	+	High ergic tension	tense, excitable, restless, impatient
	-	Low ergic tension	relaxed, satisfaction that may lead to low performance

Table XI. Creativity Specification.
(From I.P.A.T.)

Creative Pole of Factor	Personality Factor	Weighting of Source Trait Sten Score	
Reserved, cool	A-	subtract sten score from 11 multiply residual sten	x 2
Intelligent	B	multiply sten	x 2
Assertive, aggressive	E	multiply sten	x 1
Sober, serious	F-	subtract sten score from 11 multiply residual sten	x 2
Venturesome	H	multiply sten	x 1
Sensitive, tender-minded	I	multiply sten	x 2
Imaginative, "dreamer"	M	multiply sten	x 1
Forthright, artless	N-	subtract sten score from 11 multiply residual sten	x 1
Experimenting, free-thinking	Q_1	multiply sten	x 1
Self-sufficient, resourceful	Q_2	multiply sten	x 2

Note: The weights given should be used to multiply the sten scores of the individual on each of the factors indicated and the results should be added to a single score. On this combined score an average performance will be 82.5 on the 16 P.F.

an appropriate measure would be the awareness of a subject, his perceptiveness to architectural space. This has formed some part of the creativity specification. But, in an emphasis on the investigation and development of general creativity in the classroom and laboratory, dimensions of perceptiveness remain undefined. And the architect is the one most involved in these dimensions.

It has been shown that personality measurement is taken at a time when the individual is deviant, by at least some small mood state, from his average true position. In the present study definition of an average personality is not required. Importance is instead given to the measurement of an individual personality at the time of experiment. Personality factors can then be correlated with objective and subjective behaviour.

The classification of personality, subjective response, stimulation and visual preference leads to the following hypotheses:

THAT classification of the personality of a subject at the time of viewing a stereoscopic display of spatial sequence is related to his subjective response and stimulation.

THAT a record of the fixations and movements of the eyes of the subject while viewing the stereoscopic display of spatial sequence gives some insight into how the perceptive process is working and how the sequence is being evaluated.

X. CLASSIFICATION OF SUBJECTIVE RESPONSES AND STIMULATION

The polar terms lingering-movement, dominance-command and path-barrier are taken to classify beginnings for variation in subjective responses to architectural space. A questionaire in which this classification was written as a series of questions was given in Table VI. This questionaire will be used to ascertain variation of subjective responses while viewing the stereoscopic displays of spatial sequences at the Sydney Opera House.

The stimulation received by a subject from a display will be considered from two dimensions. The interest given by each display is taken to indicate the intensity of stimulation. Aesthetic evaluation of the spaces in each display would indicate the direction of stimulation.

Interest derived from a display may result from a wide range of visual stimuli — cues of colour and texture, phototropic contrasts, composition of the display from individual positions in space — and the presence of analogous or contrasting past experience. Aesthetic preferences are also dependent on varying bases for evaluation, particularly as they relate to previous conditioning. The writer has directed the scaling of stimulation intensity to the interest derived from viewing each display regardless of whether this interest stems from composition, colour, contrast or sunlight. On the other hand, aesthetic evaluation is directed to the quality of the spaces shown in each display. A questionaire for stimulation responses, Table XII, indicates this concern for a more directive basis in aesthetic evaluation.

The scaling procedure developed by Osgood (1952) for semantic differential testing has been adopted. A five-scale classification of polarity is given to the subject in which polar adjective X is opposed to polar adjective Y. The subject is asked to indicate his response as strongly X, X, neither X nor Y, Y, or strongly Y. The classification of the intensity of stimulation is presented as very interesting (2), interesting (1), neutral (0), dull (-1), and very dull (-2). The direction of the stimulation from the spaces in each display is classified as very fine (2), fine (1), neutral (0), poor (-1), and very poor (-2). The polar terms interesting-dull and fine-poor have been selected as linear polar scales whose range of meaning passes through an origin.

The scaling of stimulation responses may be graphically represented by a two-dimensional plotting, Table XIII.

Table XII. Stimulation Response Questionaire.

Please indicate the classification that would best describe each display.

	DISPLAY 1	2	3	4	5	6	7	8	9	10	11	12
very interesting												
interesting												
neutral												
dull												
very dull												

Please indicate your aesthetic evaluation of the spaces shown in each display.

	DISPLAY 1	2	3	4	5	6	7	8	9	10	11	12
very fine												
fine												
neutral												
poor												
very poor												

Table XIII. Classification of Stimulation.

Intensity of Stimulation

very interesting 2					
interesting 1					
neutral 0					
dull -1					
very dull -2					
	-2 very poor	-1 poor	0 neutral	1 fine	2 very fine

Direction of Stimulation

XI. POSTULATES AND HYPOTHESES

Postulates.

THAT the "Threshold Theory" is a valid means of analysing spatial sequences.

THAT a spatial sequence consists of points of threshold, experience and exit.

THAT these points, when isolated and recorded in the field and used as stereoscopic displays in the laboratory, can represent the spatial sequence.

Hypotheses.

THAT classification of the personality of a subject at the time of viewing a stereoscopic display of spatial sequence is related to his subjective response and stimulation.

THAT a record of the fixations and movements of the eyes of a subject while viewing the stereoscopic display of spatial sequence gives some insight into how the perceptive process is working and how the sequence is being evaluated.

EXPERIMENT

XII. APPARATUS

The photographic recording of spatial sequences at the Sydney Opera House has been described in Chapter VIII. Stereoscopic slides were taken with a Minolta SR-7 camera, f1.4/58mm Auto Rokkor lens, and Ektachrome 64 ASA film. A stereoscopic motion picture of the same sequences was photographed with a Bolex standard 16mm motion picture camera and f2.8/12.5mm Yvar stereo attachment. Ektachrome ER 160 ASA film was used.

Two Kodak Carousel S slide projectors and a Bell and Howell 16mm motion picture projector with Bolex S1 stereo projection lens were used for projection. Image separation at the screen was effected by the addition of polarizing filters to the slide projectors. The Bolex projection lens incorporated polarizing filters. The slide projectors were linked to a common remote control forward switch.

The use of polarizing filters for image separation requires a flat metallic screen surface. A screen of $\frac{3}{4}$inch prefinished chipboard was sprayed with several coats of aluminium paint and lightly sanded between applications.

A light dural frame was constructed to pivot from the sides of the head rest, Fig. 30. This supported two $4\frac{1}{2}$" x 6" x 0.132" mutually opposing polarizing filters for the subject's viewing. Absorbing screens were placed to the sides of the filters to prevent reflections from projection lenses.

A reclining chair, on loan from the Edinburgh Royal Infirmary, was slightly modified to provide comfortable positioning of the subjects while viewing the screen. An Austi car-rally head rest was fixed to the reclining chair, Fig. 30.

The electronic recording of eye fixations was carried out with equipment manufactured to specifications by Shackel (1958, 1959, 1960). Electrolyte/metal-salt/metal electrodes were supplied by Specialized Laboratory Equipment. These electrodes have high electrical stability and are supplied complete with rubber suction cups,

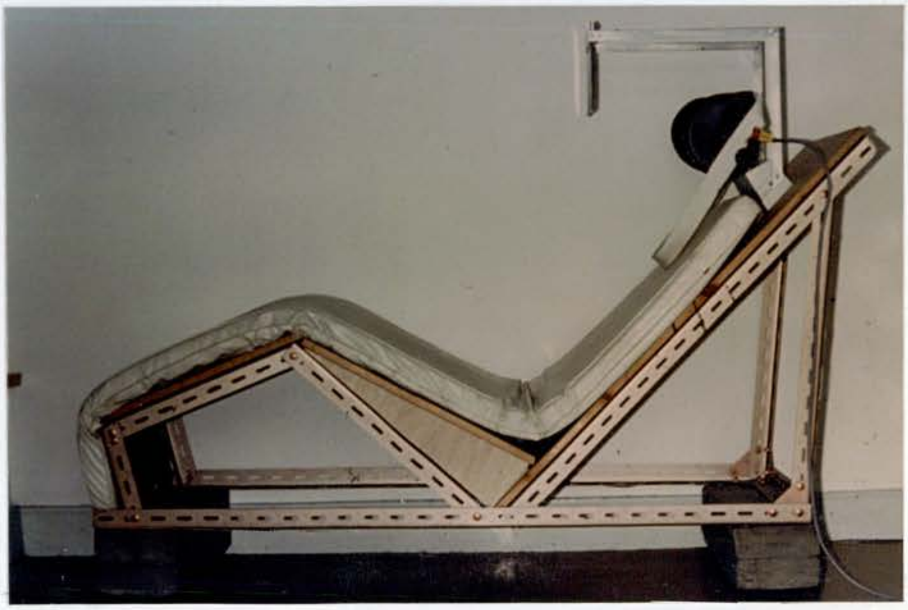


Fig. 30. Reclining Chair
with Frame supporting
Polarizing Filters.

Fig. 31. For the main study a set of five electrodes was used, for special tests of convergence a set of seven. With DC amplification and skin drilling, the average zero drift from electrodes was 50µv per minute.

A 1.5 volt battery operated hand drill was fitted with a Dica 102 spherical dental burr for the skin drilling of electrode positions.

A Medelec N8 nesting unit with three EM8 amplifiers was used for amplification of eye potentials. A detail of this equipment is shown in Fig. 32. Two Solartron CD1400 oscilloscopes, each with two CX1442 amplifiers and a CX1571 x-y unit,

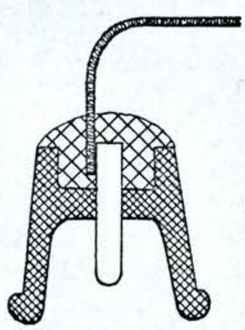


Fig. 31. Rubber Suction Cup Electrode. Section. (From Shackel)

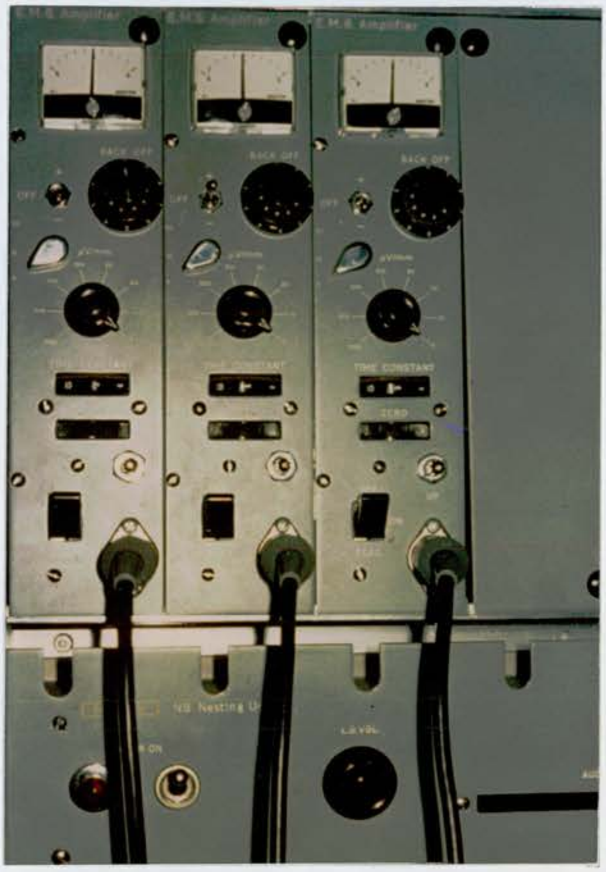


Fig. 32. Medelec EM8 Amplifiers.

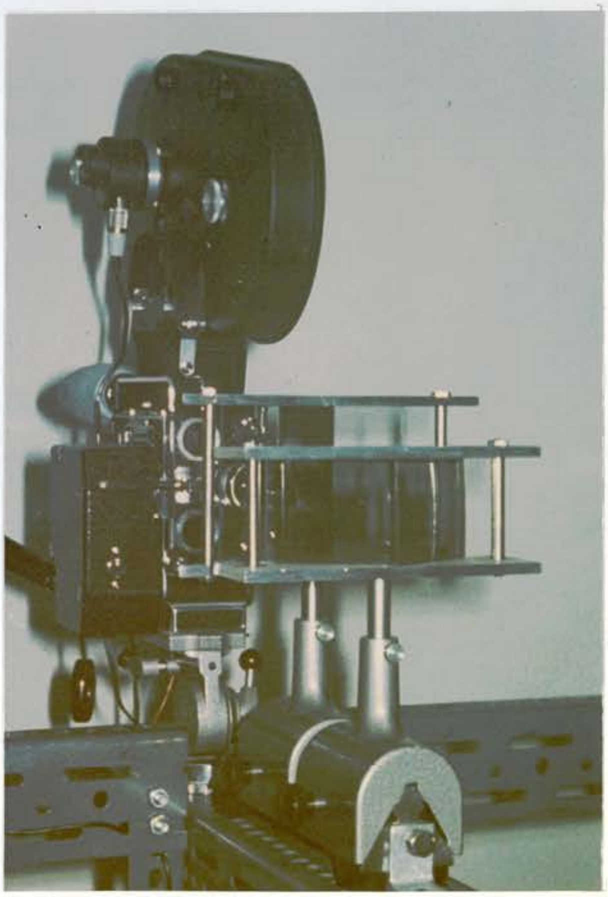


Fig. 33. Optical Bench.

were connected to the Medelec equipment. Equipment tests were carried out using ±100μv and ±500μv signals derived from a Wheatstone bridge arrangement. One 400ohm and three 100ohm Muirhead resistors 0.1% tolerance were used as bridge arms, and a 250ohm multi-turn precision helical potentiometer in parallel with a 400ohm resistor provided accurate settings of voltage levels. The detector used was a Solartron digital voltmeter. The calibrated voltages were then displayed on an oscilloscope in order to ascertain ripple amplitude.

The left and right image of each display was photographed through an optical bench. Two 2½" x 3" lenses with polarizing filters separately focused the two images from the screen. Two 4" x 3" planes of 1mm glass were set at 45^{o} to the line of photography in order to reflect the oscilloscope trace on to the photographic path. A detail of the optical bench is shown in Fig. 33.

A diagrammatic plan of the equipment is given in Fig. 34 and a photograph from the screen in Fig. 35. The oscilloscope trace of eye fixations was superimposed onto the two images from the projection screen and photographed with a Bolex Rx5 16mm motion picture camera and 400-ft magazine. A 24 f.p.s. MST motor was driven from a 12volt car battery. Kodak Tri-X 200 ASA film was used.

The analysis of eye fixations was carried out with a Minette 16 Viewer Editor.

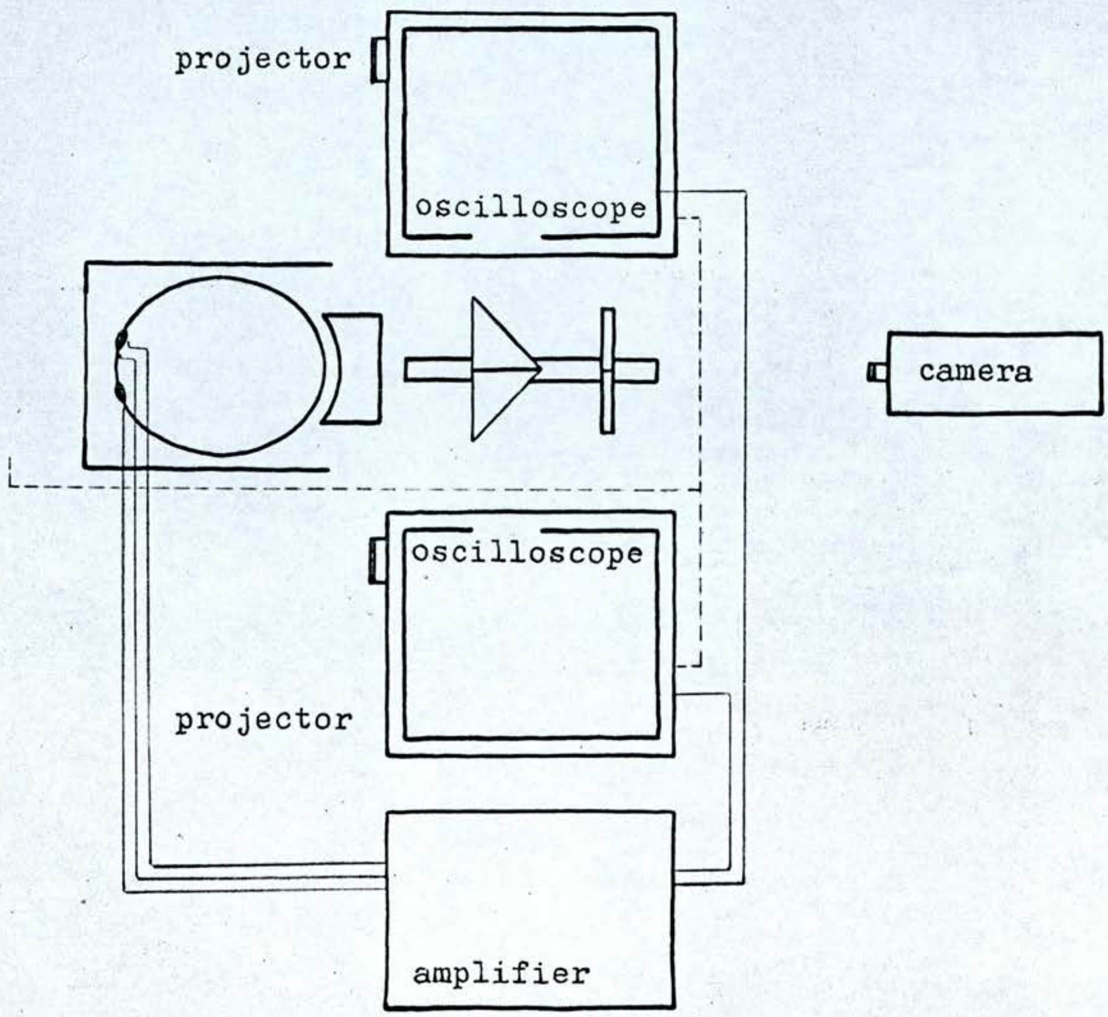


Fig. 34. Diagrammatic Plan of Equipment.

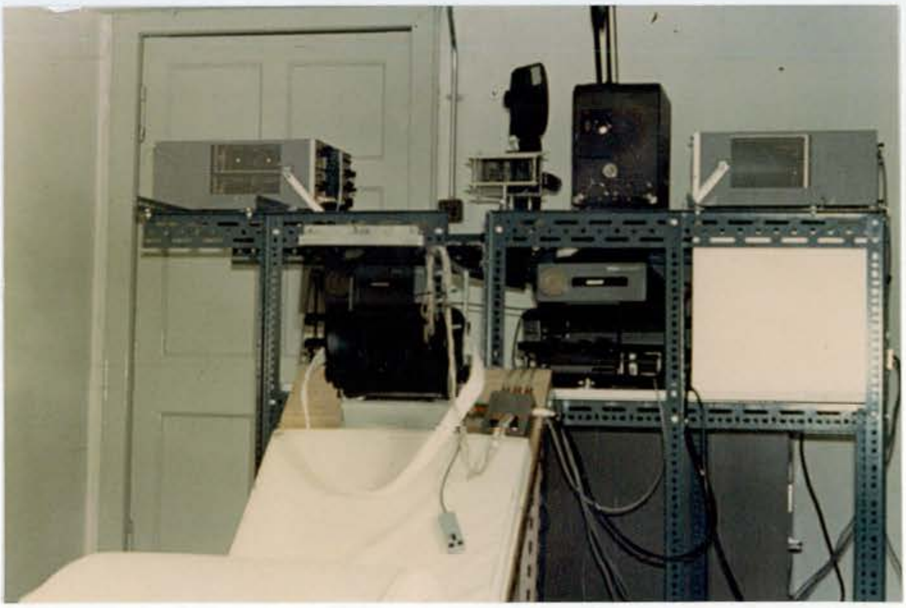


Fig. 35. Equipment.

XIII. METHOD

A precise preparation technique is an essential part of the total procedure of recording eye fixations by electro-oculography.

In the preparation of electrode jelly all containers and utensils were particularly clean. The formula for the jelly was 1gm Sodium Chloride and 2gms Agar to 100cc distilled water. Chemicals were of analar quality. A little distilled water was slowly added to the 2gms Agar to form a thick paste. With continuous stirring the remainder of the distilled water was added and finally the 1gm Sodium Chloride. The mixture was heated to 95^{o}C. After cooling for a few minutes the clear liquid was decanted off into two wide-mouthed 60cc specimen jars. As the mixture cooled from 40^{o}C to room temperature it was stirred continuously to form a smooth liquid jelly. This was kept airtight in the specimen jars by ground glass tops.

Before an experiment the electrodes were taken from an airtight container, rinsed in distilled water, and then soaked for two hours in 1% Sodium Chloride solution. Care was taken that there were no air bubbles in the electrode cups. While in the saline solution the leads were shorted together by a cross-wired valveholder.

The oscilloscope and amplifiers were switched on at least two hours prior to the commencement of the experiment.

On arrival the subject was assured that the experiment was not a performance test and that the first part of it was simply to "run through" a series of slides at his own speed. He was seated in the reclining chair and given the forward switch to the projectors. The instruction given was that he would take over control of the projectors as soon as the first display was projected. The height of the head rest was adjusted so that the subject's eyes were level with the centre of the screen.

Cetavlon was swabbed over the skin surface at the areas for electrode attachment.

The horizontal axis through the pupils of both eyes was accurately marked on the skin surface with a dermatograph pencil. The vertical axis through the pupil of the left eye was similarly marked. The skin surface on the neck was also cleaned with cetavlon and marked ready for skin drilling.

The rotating burr of the hand drill was applied lightly to the skin surface at each position several times until a shallow, circular depression was made in the epidermis. The correct depth was indicated by a slight glistening of tissue in the depression. Acetone applied to the depression of a correctly drilled electrode position led to a tingling or stinging sensation.

Following the drilling of the skin for the horizontal and vertical sets of electrodes and the earth electrode, the subject's head was held against the head rest by a forehead band. A velcro surface to the band adhered to a corresponding surface at the back of the head rest and this provided a rapid means of head stability.

The electrode leads were plugged into the socket on the input cable to the amplifier. The oscilloscope trace of the shorted electrodes in the saline solution was viewed to assure electrode stability, and the electrodes were then independently removed from the saline solution, shaken to remove surplus drops, and filled with saline jelly. A disposable 1cc hyperdermic syringe, without needle, was used to withdraw the electrode jelly from the specimen jar and apply it to the suction cup of the electrode. The cup was squeezed so that the jelly protruded and was then pressed to its drilled position on the skin. With experience the release of the cup assured a firm suction without discomfit to the subject. The positioning of electrodes is shown in Fig. 36.

The polarizing filters for the subject's viewing, which were supported by the frame pivoted to the sides of the head rest, were brought in front of the eyes. The lights in the room were turned off leaving only the projection of a calibration slide, Fig. 37. Luminous points had been affixed to the oscilloscope screens to correspond with positions on the calibration slide. When viewed through the camera lens and optical bench the two sets of calibration points coincided.

The subject was instructed to fixate the centre zero calibration point on the screen. The residual standing potential was backed-off on the amplifiers. With correctly prepared electrode

Fig. 36. Positioning of
Electrodes.

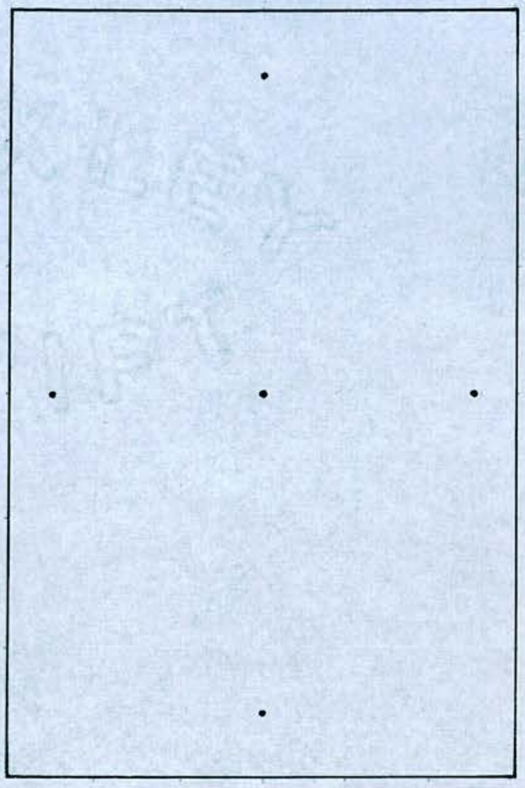


Fig. 37. Calibration Slide.

contact points the residual standing potential was usually less than lmv. The subject was then asked to fixate calibration points above, below, left and right of the centre zero point. The eye fixations were displayed on the oscilloscope screen and gain was adjusted from the amplifier unit. The trace of eye fixations, together with superimposed calibration points, was seen through the camera lens.

Four calibration slides were inserted into the series of stereoscopic displays as indicated in

Table XIV. It is seen that calibration slides were inserted in the sequence only between stereoscopic slides taken from the same camera position. These have been referred to as displays of experience in Chapter VIII. Displays 1-12 are illustrated in Fig. 40.

Full calibrations, using the known points above, below, left and right of the centre zero point were carried out for each calibration slide. The centre point was fixated by the subject immediately prior to the projection of displays 1, 4 and 10. The motion picture camera was switched on at these times. The subject controlled the viewing time for displays 1 to 3. As soon as the

Table XIV. Displays.

DISPLAY	Classification
Calibration slide	Fig. 37.
1	Experience
2	Threshold
3	Experience
Calibration slide	Fig. 37.
4	Experience
5	Exit
6	Threshold
7	Experience
8	Exit
9	Experience
Calibration slide	Fig. 37.
10	Experience
11	Threshold
12	Experience
Calibration slide	Fig. 37.

calibration slide following display 3 came on to the screen the subject again fixated the zero point and a full calibration was carried out. The centre point was again fixated and display 4 projected. The subject controlled the viewing time until the calibration slide following display 9 came on to the screen. The calibration procedure was repeated before proceeding to display 10.

Following the recording of eye fixations, the subject was given the subjective response and stimulation questionaires, Tables VI and XII. The electrodes were removed and thoroughly rinsed in distilled water to remove the electrolyte. All cleaning solutions were used once only. The subject read the subjective response and stimulation questionaires and then viewed display 1 for 5 seconds to remind him of it. The lights in the room were turned on and the questionaires answered from memory of the spaces shown in the display. The lights were turned off and display 2 was projected for 5 seconds. This procedure was repeated for all displays.

On completion of the subjective response and stimulation questionaires the subject moved to an adjacent desk and completed Form B of the 16

Personality Factor Questionaire.

The approximate time taken for each part of the experiment is given in Table XV.

Table XV. Approximate Time for Experiment.

Time	Description
15 - 20 minutes	Preparation, skin drill and attaching electrodes
5	Calibration and viewing time
10	Subjective response and stimulation questionaires
30 - 40	Personality questionaire
60 - 75 minutes	Total time of experiment

Upon completion of the experiment, the subject's skin at the electrode positions was cleaned with acetone to remove the marks of the dermatograph pencil. Lanolin cream was then rubbed into the skin at the drilled areas. The pressure rings from the rims of the electrodes had disappeared before the end of the experiment. The marks from skin drilling were visible for three or four days.

The above procedure was carried out for forty subjects. These represented a wide range of cultural backgrounds. Seventy-five percent of the subjects were unknown to the writer prior to the experiment, having been referred by other subjects who had taken the test. In order to obtain a wide range of responses a classification was established and adhered to such that additional subjects in any classification were not included in the experiments. Instead, the writer waited for contact with subjects in the remaining unfilled groups. The classifications established were for architects, architectural students, professional subjects other than architects, and non-professional subjects. Each group of ten subjects was equally divided between male and female. The forty subjects then provided a range of variation in training and conditioning but did not represent a sample of the general population.

Three special tests were carried out in electro-oculography.

One subject, in addition to participation in the main study, viewed the series of stereoscopic slides on two further occasions. Each occasion was separated by more than three weeks. Recordings of eye fixations, subjective responses and stimulation were obtained on each occasion.

The recording of convergent eye movements was attempted for two subjects using a set of electrodes on the horizontal axis of each eye in addition to the vertical set and the earth electrode. One subject viewed the series of stereoscopic displays, the other viewed a stereoscopic motion picture of the same spatial sequence.

Two further subjects viewed the stereoscopic motion picture and the series of stereoscopic slides. The subjects viewed the stereoscopic motion picture immediately prior to viewing the series of slides. A questionaire of the importance and appropriateness of each display relative to the stereoscopic motion picture was given to these subjects. The questionaire and results are given later in Table XXIX.

A grid of black cord was formed over the projection screen for photometric analysis, Fig. 38. A similarly proportioned grid was applied to the screen of the Minette 16 Viewer Editor for analysis of eye fixations. The grid divided the display into 36 sectors. On the projection screen the display was 38 inches in width and 60 inches in height. The width and height were divided into six parts so that

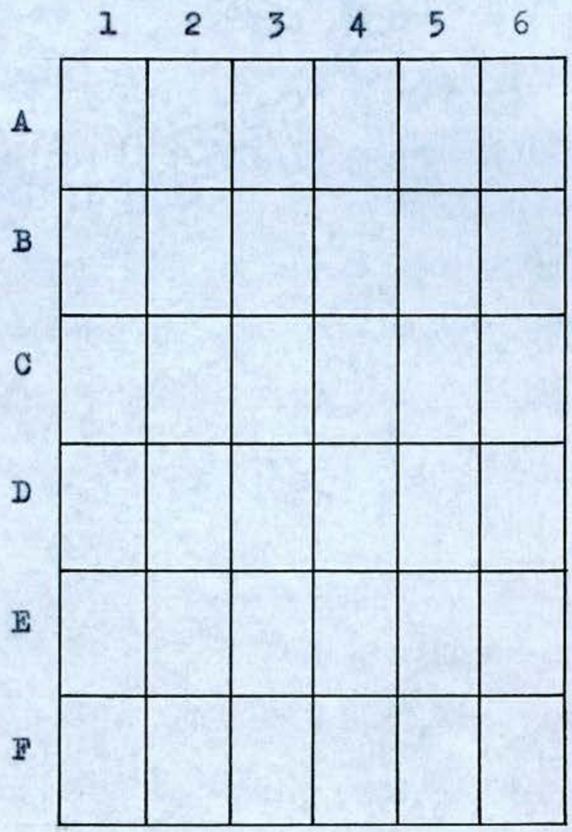


Fig. 38. Grid for Sector Analysis.

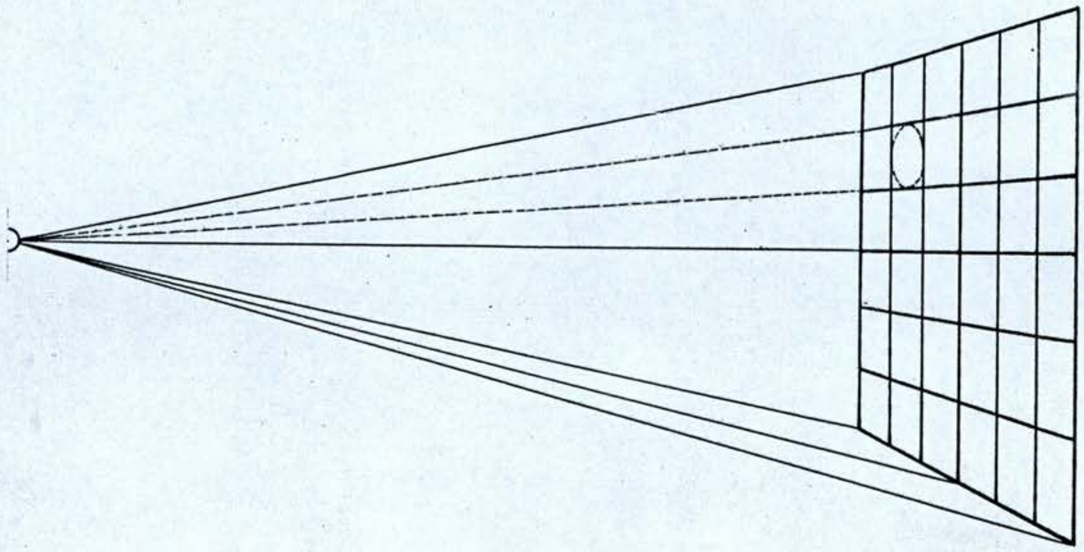
each sector was 6.3 inches by 10 inches. The grid on the oscilloscope screen was 1cm horizontally and 1.6cm vertically. For all analyses the sectors were described as in Fig. 38.

The grid design was based on the total precision of instrumentation. The accuracy of the location of the oscilloscope trace was such that a fixation could be marked on the oscilloscope screen to within ±0.5cm in the horizontal plane and ±0.8cm in the vertical plane. This represented an accuracy on the projection screen of within ±3 inches horizontally and ±5 inches vertically. The display was viewed from a distance of twelve feet so that eye fixations were placed to an accuracy of within $\pm 1\frac{1}{4}^{\circ}$ of visual angle in the horizontal plane and $\pm 2^{\circ}$ in the vertical plane. Angular measurements from subject to grid divisions on the screen are given in Fig. 39.

The greater accuracy in placing fixations in the horizontal plane compared to the vertical plane is dependent on the amplitude of eye potentials. The $\pm 1\frac{1}{4}^{\circ}$ horizontal and $\pm 2^{\circ}$ vertical accuracy is in agreement with the figures given by Shackel (1960).

The analysis of eye fixations was carried out in two parts. The first was a diagram of fixation sequence which recorded the initial eye fixation and eye movements to subsequent fixations. The second part added together the unit fixations which occurred in each sector. The eye fixation sequence and the sector analysis of unit eye fixations was obtained for all subjects in Displays 4, 6, 7, 8, 9 and 11. In addition to this the eye fixations to all displays were analysed for a number of subjects.

A photometric analysis of Displays 4, 6, 7, 8,



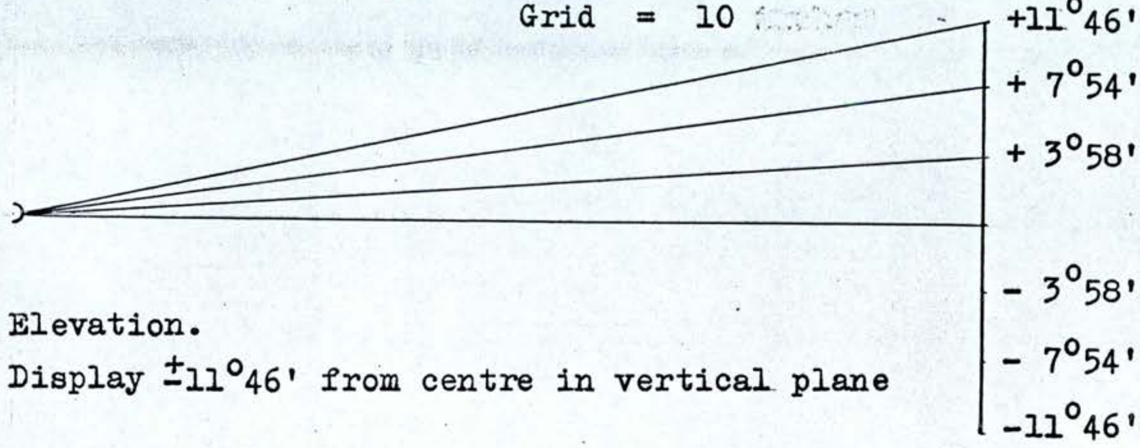
Grid design:

Horizontal: $x = \tan 1\frac{1}{4}^{o} \,.\, 144 = 3.15$ inches

Grid $= 6.3$ [illegible]

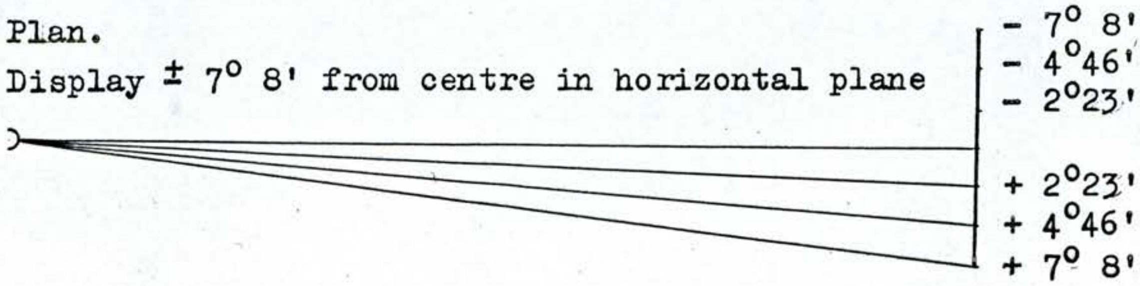
Vertical: $y = \tan 2^{o} \,.\, 144 = 5$ inches

Grid $= 10$ [illegible]



Elevation.

Display ±11°46' from centre in vertical plane



Plan.

Display ± 7° 8' from centre in horizontal plane

Fig. 39. Angular Measurements.
Subject to Screen.

9 and 11 was made in two parts. The first was to obtain a measure of the average brightness in each sector, the second was to calculate the brightness range in each sector. In sensitometry the transmission of light is defined in relationship to opacity and density as follows:

$$\text{Density} = \text{log. opacity} = \text{log.} \frac{1}{\text{transmission}}$$

This is illustrated in Table XVI.

Table XVI. Density, Opacity and Transmission.

Density	Opacity	Transmission
0.0	1.0	100 %
0.2	1.6	63
0.4	2.5	40
0.6	4.0	25
0.8	6.3	16
1.0	10.0	10
1.2	16.0	6.3
1.4	25.0	4.0
1.6	40.0	2.5
1.8	63.0	1.6
2.0	100.0	1.0

The average density of each sector of the stereoscopic display was obtained with a Joyce double beam Microdensitometer Mk IIIB in the Department of Natural Philosophy, Edinburgh University. The two slides of each stereopair were in turn placed on top of each other on the densitometer and the slit of light adjusted to the width of the vertical grid division. Graphs were obtained for the six vertical grid divisions of the six displays. Each graph was later divided into six parts to correspond to the A to F horizontal grid divisions. The average density for each sector was obtained directly from these graphs.

The second part of the photometric analysis was carried out during projection of the stereoscopic displays. The displays were viewed by the writer from the position of the subject and a SEI Exposure Photometer was used to subjectively discriminate the minimum and maximum brightness in each sector. Following the viewing of each sector the writer returned to an initial sector to check on subjective adaptation. The luminance contrast was calculated for the maximum luminance L_1 and the minimum luminance L_2 as follows:

$$\text{Luminance contrast} = \frac{L_1 - L_2}{L_1}$$

The results of the photometric analysis are included in Chapter XIV.

Display 1.

Display 2.

Fig. 40(1-12) Displays of Spatial Sequences,
The Sydney Opera House.
(Right Images)

Display 3.

Display 4.

Fig. 40(1-12) Displays of Spatial Sequences, The Sydney Opera House. (Right Images)

Display 5.

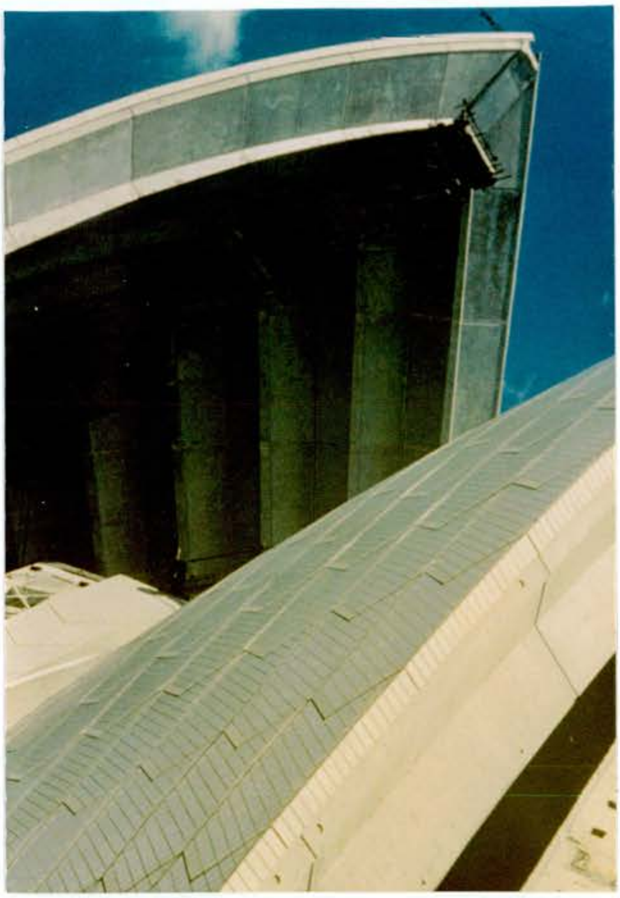
Display 6.

Fig. 40(1-12) Displays of Spatial Sequences, The Sydney Opera House. (Right Images)

Display 7.

Display 8.

Fig. 40(1-12) Displays of Spatial Sequences,
The Sydney Opera House.
(Right Images)

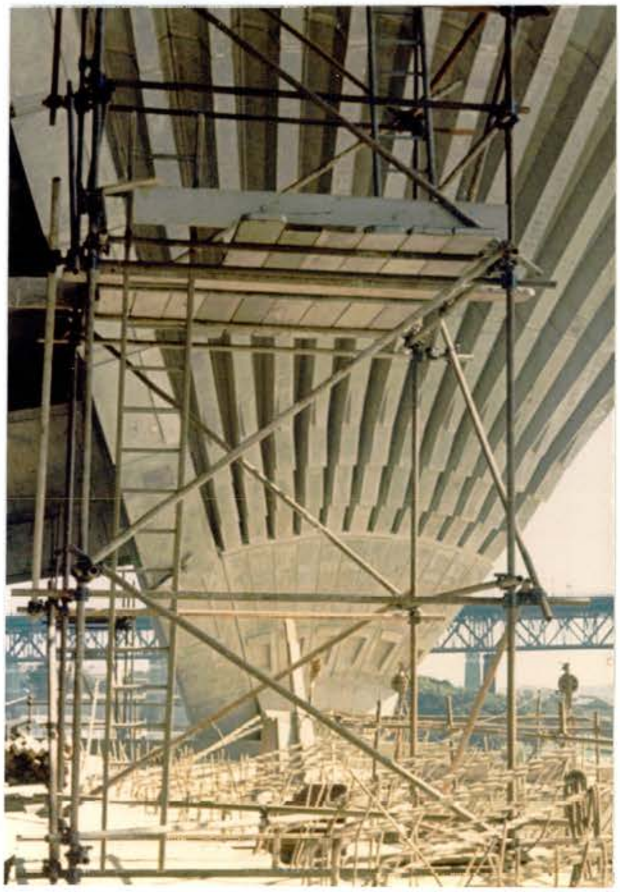


Display 9.

Display 10.

Fig. 40(1-12) Displays of Spatial Sequences, The Sydney Opera House. (Right Images)

Display 11.



Display 12.

Fig. 40(1-12) Displays of Spatial Sequences, The Sydney Opera House. (Right Images)

XIV. RESULTS

Subjective responses of the forty subjects to the twelve stereoscopic displays are given in Table XVII. The subjective response questionaire was given in Table VI. The combinations of the subjective responses for each display are listed in Table XVIII.

Stimulation responses for each display are given in Table XIX. In the stimulation response questionaire, Table XII, two dimensions of stimulation were presented. The classification of the intensity of stimulation was presented as very interesting, interesting, neutral, dull or very dull. The direction of stimulation was classified as very fine, fine, neutral, poor or very poor. The stimulation responses of the forty subjects to each display are plotted in these two dimensions, Fig. 41. The figures on the intensity (vertical) scale for each display indicate the number of subjects responding to each classification of intensity. These figures have then been weighted so that the

Table XVII. Subjective Responses.
Results from Questionaire, Table VI.

	DISPLAY											
	1	2	3	4	5	6	7	8	9	10	11	12
Linger.	8	20	24	16	18	5	35	3	18	10	14	20
Move through.	26	12	11	24	14	32	3	34	11	20	26	7
Inapprop.	6	8	5		8	3	2	3	11	10		13
Dominating.	20	13	24	22	29	10	4	12	30	11	24	28
Command.	14	17	10	14	4	25	31	21	4	21	15	5
Inapprop.	6	10	6	4	7	5	5	7	6	8	1	7
Path.	26	11	16	36	12	36	10	35	10	20	33	9
Barrier.	13	25	19	3	9	2	20	5	19	16	3	25
Inapprop.	1	4	5	1	19	2	10		11	4	4	6

Table XVIII. Combinations of Subjective Responses.

	DISPLAY											
	1	2	3	4	5	6	7	8	9	10	11	12
Linger, Dominating, Path		2	2	10	4	1	1		1		7	3
Linger, Command, Path	3	1	1	4		3	5	2		3	1	
Linger, Dominating, Barrier	4	6	10	1	4	1	3	1	10	2	2	11
Linger, Command, Barrier		6	2	1			14		1	4		2
Move through, Dominating, Path	13	3	5	10	3	7		7	7	2	12	1
Move through, Command, Path	5	3	4	8	2	22	3	19	2	10	12	2
Move through, Dominating, Barrier	2		2	1				3	1	4		1
Move through, Command, Barrier	4	2			1					1	1	
Linger, Dominating, Inapprop		1	3		8				3		2	2
Linger, Command, Inapprop		1	2		1		8				1	
Move through, Dominating, Inapprop					5				1		1	2
Move through, Command, Inapprop		1		1								1
Linger, Inapprop, Path	1		2				1				1	1
Linger, Inapprop, Barrier		3	2		1		1		1	1		1
Move through, Inapprop, Path	2	2		4	2	2		5		3		
Move through, Inapprop, Barrier		1										
Inapprop, Dominating, Path			1		1							1
Inapprop, Command, Path	1									1		
Inapprop, Dominating, Barrier	1	1	1		2	1		1	4	3		7
Inapprop, Command, Barrier		2	1				1		1			
Inapprop, Inapprop, Path	1		1			1		2		1		1
Inapprop, Inapprop, Barrier	2	4	1		1		1		1	1		3
Inapprop, Dominating, Inapprop					2				3			
Inapprop, Command, Inapprop	1	1								2		
Linger, Inapprop, Inapprop							2		2			
Move through, Inapprop, Inapprop					1	1						
Inapprop, Inapprop, Inapprop					2	1			2	2		1

Table XIX. Stimulation Responses.
Results from Questionaire, Table XII.

	DISPLAY											
	1	2	3	4	5	6	7	8	9	10	11	12
very interesting	11	4	19	20	8	2	10	19	25	13	23	12
interesting	18	15	18	14	16	12	23	14	14	17	15	13
neutral	8	10	2	5	9	13	6	4		5	2	12
dull	3	11	1		6	11	1	3		5		2
very dull				1	1	2			1			1

very fine	5	4	10	17	5	2	5	11	19	7	18	9
fine	15	7	11	10	14	9	20	16	13	12	13	11
neutral	13	17	12	7	14	14	10	7	5	13	7	11
poor	4	9	6	5	5	9	3	5	3	4	2	7
very poor	3	3	1	1	2	6	2	1		4		2

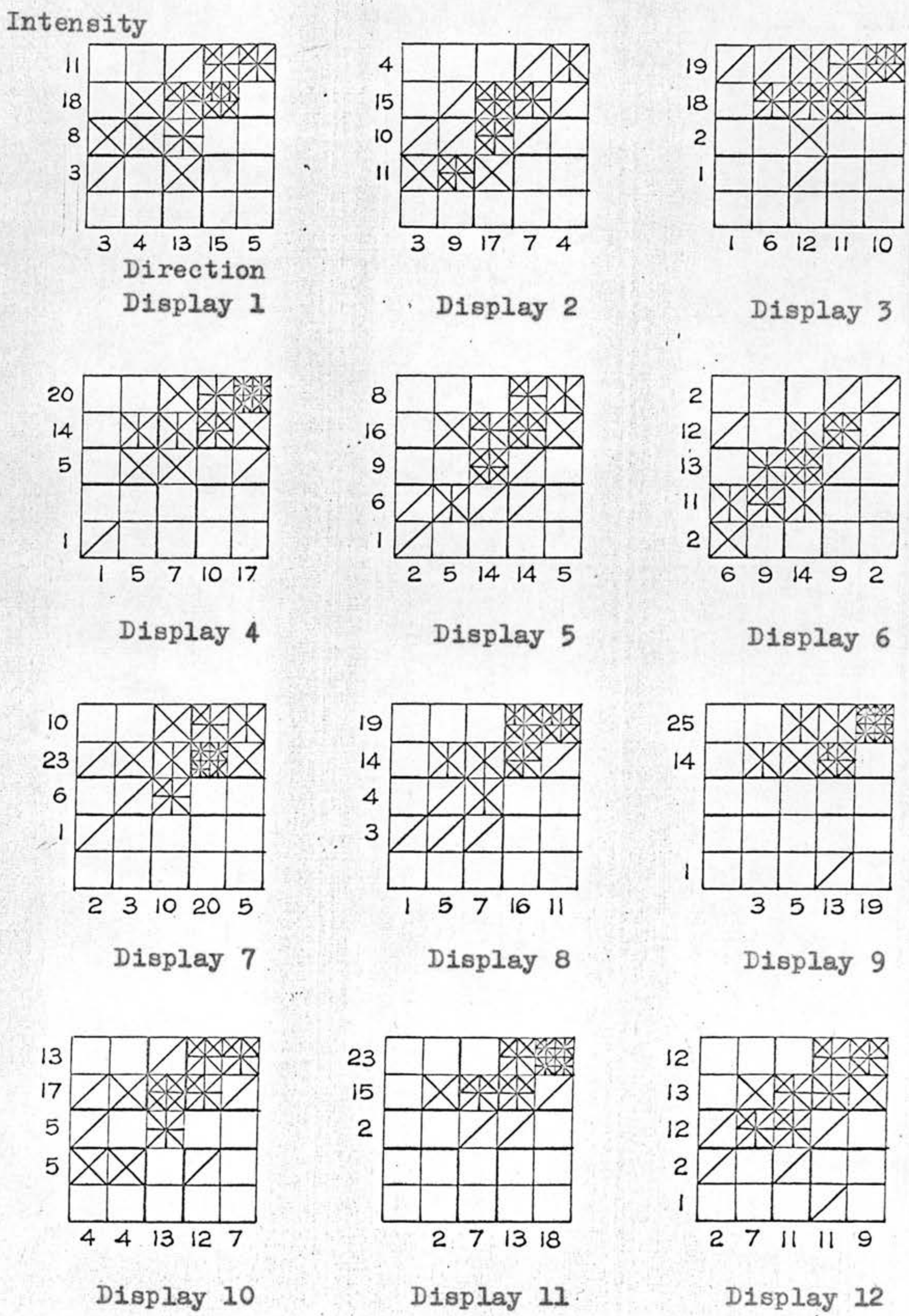


Fig. 41. Plotting of Stimulation Responses.

classification of very interesting received 2 points, interesting 1, neutral 0, dull -1, very dull -2 on the intensity scale. The total negative intensity score was then subtracted from the total positive intensity score to give the intensity of stimulation score for each display. The figures on the direction (horizontal) scale were similarly weighted to obtain the direction of stimulation score for each display. The procedure will be illustrated from the intensity scores of Display 1. From Fig. 42 it is seen that eleven subjects responded to the very interesting classification and eighteen subjects to the interesting classification. The positive intensity score is then (11 x 2) + (18 x 1) = 40. Neutral responses are ignored, and the negative intensity score is 3. The intensity of stimulation score is then 40 - 3 = 37. The intensity of stimulation score and the direction of stimulation score for each display is given in Table XX. The scores are plotted in two dimensions in Fig. 42 to provide a classification of the displays from stimulation responses.

In the experiment the viewing time for each display was controlled by the subject. The figures, Table XXI, are designated unit fixations and indicate the number of frames recorded by the motion picture camera. The film was photographed at 24 frames per

Table XX. Intensity and Direction of Stimulation Scores.

Display	Intensity of Stimulation Score	Direction of Stimulation Score
1	37	15
2	12	0
3	55	23
4	52	37
5	24	15
6	1	-8
7	42	23
8	49	31
9	62	48
10	38	14
11	61	47
12	33	18

second so that the viewing time in seconds is readily obtained. The form of unit fixations was kept for ranking purposes. The recording of eye fixations to Display 12 was incomplete in the case of six subjects. For these subjects the mean viewing time for the remaining eleven displays has been inserted for Display 12 and shown in brackets whenever this is reflected in the results.

In all listings of the forty subjects the first group of ten were architects, the second group architectural students, then professional subjects other than architects, and non-professional subjects.

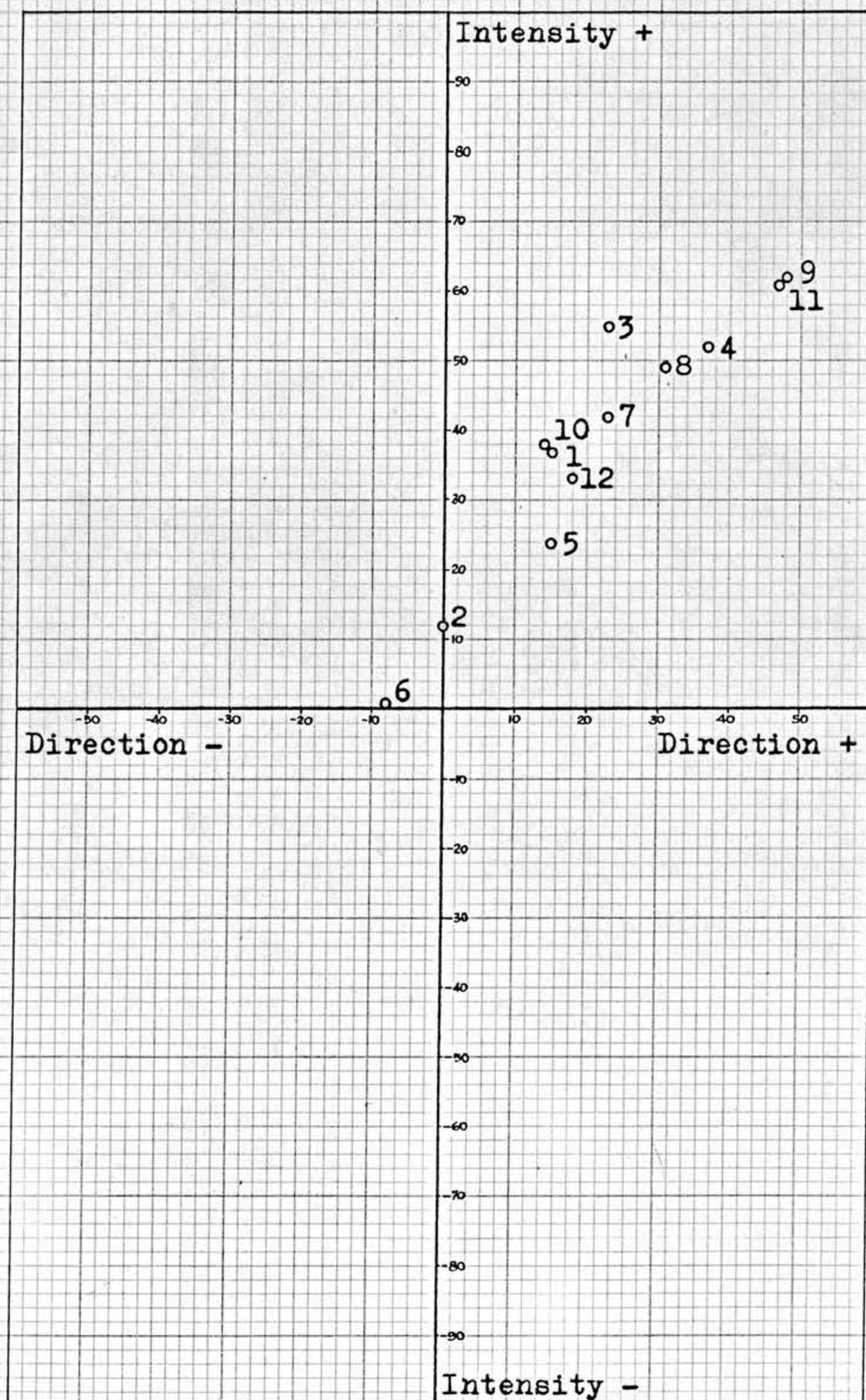


Fig. 42. Classification of Displays from Stimulation Responses.

Table XXI. Viewing Time in Unit Fixations.

Subject	DISPLAY 1	2	3	4	5	6	7	8	9	10	11	12	Mean	Total
1	382	421	417	513	444	417	441	550	510	450	540	inc	462	(5547)
2	397	487	355	250	229	191	159	196	208	249	194	168	257	3083
3	238	576	363	621	515	287	321	405	513	845	557	316	463	5557
4	102	105	72	95	100	108	106	119	90	60	101	91	96	1149
5	582	632	278	779	556	457	723	456	491	499	294	511	522	6258
6	1065	214	203	236	205	222	259	339	255	328	246	378	329	3950
7	100	47	82	73	50	65	75	73	79	95	79	64	73	882
8	93	89	102	91	95	98	106	99	187	113	157	113	112	1343
9	510	260	341	240	199	204	256	217	194	179	235	175	251	3010
10	251	315	529	448	410	344	359	572	539	424	495	470	430	5156
11	290	630	395	362	377	159	200	195	196	132	222	239	283	3397
12	301	230	270	472	307	236	230	416	418	504	470	inc	350	(4204)
13	310	190	227	209	164	98	204	190	245	97	213	226	198	2373
14	125	179	250	189	206	196	305	304	173	153	273	285	220	2638
15	119	58	91	84	57	56	83	99	90	119	153	119	94	1128
16	217	430	763	694	647	335	452	694	491	843	484	inc	550	(6600)
17	370	291	475	540	554	779	593	610	715	590	650	inc	561	(6728)
18	104	71	79	89	73	79	85	108	95	71	85	72	84	1011
19	307	412	349	437	303	210	296	276	196	389	213	181	297	3569
20	136	84	150	84	110	103	109	126	128	110	112	102	113	1354
21	507	234	242	477	287	303	650	311	304	583	524	375	400	4797
22	109	112	142	94	139	94	115	175	177	154	178	191	140	1680
23	106	123	106	137	128	127	127	123	153	136	170	128	130	1564
24	100	96	89	155	232	126	132	138	110	225	114	148	139	1665
25	148	143	139	129	152	70	132	176	192	143	169	134	144	1727
26	130	128	105	103	97	62	103	106	68	86	143	103	103	1234
27	125	117	91	77	81	78	83	53	92	90	89	117	91	1093
28	408	208	231	249	262	414	493	318	624	510	539	651	409	4907
29	256	200	235	189	254	166	261	270	279	327	285	244	247	2966
30	701	482	566	482	503	251	247	601	465	599	487	375	480	5759
31	423	503	242	255	87	124	113	260	214	183	225	170	233	2799
32	354	482	392	294	261	246	451	287	393	328	284	inc	343	(4115)
33	185	190	359	400	375	331	437	322	348	499	587	inc	367	(4400)
34	620	493	719	720	698	696	1017	663	938	985	969	610	761	9128
35	195	344	311	211	211	271	392	291	213	115	157	244	246	2955
36	713	354	412	370	393	295	332	347	287	561	411	432	409	4907
37	92	72	84	71	97	66	75	60	92	73	98	94	81	974
38	583	289	298	317	351	239	431	379	497	435	518	253	383	4590
39	111	110	111	91	198	157	128	194	245	186	230	134	158	1895
40	58	45	81	37	45	38	32	44	56	35	41	40	46	552
	11923	9446	10746	11364	10452	8798	11113	11062	11560	12503	11991	(10586)		Total
	298	236	269	284	261	220	278	277	289	313	300	(234)		Mean

In each group the five female subjects are listed first and, in each subgroup of female or male subjects, the subjects are listed in descending age.

The percentage viewing time for each display is given in Table XXII. For each subject the number of unit fixations for each display is divided by the total unit fixations for the twelve displays.

The photometric analysis of Displays 4, 6, 7, 8, 9 and 11 was described in Chapter XIII. A graph of the density recording from the Joyce Micro-densitometer for sectors A6 to F6, Display 11, is given in Fig. 43. Graphs were obtained for the six vertical grid divisions of the six displays. Each graph was later divided into six parts for the A to F horizontal grid divisions. Figures of the average density of each sector, Fig. 44, were obtained directly from the graphs. The luminance contrast in each sector is also given in Fig. 44.

The photometric analysis of the density and luminance contrast of each sector was expressed graphically and compared with the graphical representation of percentage unit eye fixations in each sector. This comparison was made for Displays 4, 6, 7, 8, 9 and 11 and is illustrated for Display 4, Fig. 45.

Table XXII. Percentage Viewing Time.

	DISPLAY											
Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	(6.9)	(7.6)	(7.5)	(9.3)	(8.0)	(7.5)	(8.0)	(9.9)	(9.2)	(8.1)	(9.7)	(8.3)
2	12.9	15.8	11.5	8.1	7.4	6.2	5.1	6.4	6.7	8.1	6.3	5.5
3	4.3	10.4	6.5	11.2	9.3	5.1	5.8	7.3	9.2	15.2	10.0	5.7
4	8.9	9.1	6.3	8.3	8.7	9.5	9.2	10.3	7.8	5.2	8.8	7.9
5	9.3	10.1	4.4	12.4	8.9	7.3	11.6	7.3	7.9	8.0	4.7	8.1
6	26.9	5.4	5.1	6.0	5.2	5.6	6.6	8.6	6.5	8.3	6.2	9.6
7	11.3	5.3	9.3	8.3	5.7	7.4	8.5	8.3	8.9	10.8	8.9	7.3
8	6.9	6.6	7.6	6.8	7.1	7.3	7.9	7.4	13.9	8.4	11.7	8.4
9	17.0	8.6	11.3	8.0	6.6	6.8	8.5	7.2	6.4	6.0	7.8	5.8
10	4.9	6.1	10.2	8.9	7.9	6.7	6.9	11.1	10.4	8.2	9.6	9.1
11	8.5	18.6	11.6	10.7	11.1	4.7	5.9	5.7	5.8	3.9	6.5	7.0
12	(7.2)	(5.5)	(6.4)	(11.2)	(7.3)	(5.6)	(5.5)	(9.9)	(9.9)	(12.0)	(11.2)	(8.3)
13	13.1	8.0	9.6	8.8	6.9	4.1	8.6	8.0	10.3	4.1	9.0	9.5
14	4.8	6.8	9.5	7.2	7.8	7.4	11.5	11.5	6.5	5.8	10.4	10.8
15	10.6	5.1	8.1	7.4	5.0	4.9	7.4	8.8	8.0	10.6	13.5	10.6
16	(3.3)	(6.5)	(11.6)	(10.5)	(9.8)	(5.1)	(6.9)	(10.5)	(7.4)	(12.8)	(7.3)	(8.3)
17	(5.5)	(4.3)	(7.1)	(8.0)	(8.2)	(11.6)	(8.8)	(9.1)	(10.6)	(8.8)	(9.7)	(8.3)
18	10.3	7.0	7.8	8.8	7.2	7.8	8.4	10.8	9.4	7.0	8.4	7.1
19	8.6	11.5	9.8	12.2	8.5	5.9	8.3	7.7	5.5	10.9	6.0	5.1
20	10.0	6.2	11.1	6.2	8.1	7.6	8.1	9.3	9.4	8.1	8.3	7.6
21	10.6	4.9	5.0	10.0	6.0	6.3	13.5	6.5	6.3	12.2	10.9	7.8
22	6.5	6.7	8.4	5.6	8.3	5.6	6.8	10.4	10.5	9.2	10.6	11.4
23	6.8	7.8	6.8	8.8	8.2	8.1	8.1	7.8	9.8	8.7	10.9	8.2
24	6.0	5.8	5.4	9.3	13.9	7.6	7.9	8.3	6.6	13.5	6.8	8.9
25	8.6	8.3	8.0	7.5	8.8	4.0	7.6	10.2	11.1	8.3	9.8	7.8
26	10.5	10.4	8.5	8.3	7.9	5.0	8.3	8.6	5.5	7.0	11.7	8.3
27	11.4	10.7	8.3	7.0	7.4	7.1	7.6	4.9	8.4	8.3	8.2	10.7
28	8.3	4.2	4.7	5.1	5.3	8.5	10.0	6.5	12.7	10.4	11.0	13.3
29	8.6	6.8	7.9	6.4	8.6	5.6	8.8	9.1	9.4	11.0	9.6	8.2
30	12.2	8.4	9.8	8.4	8.7	4.3	4.3	10.4	8.1	10.4	8.5	6.5
31	15.1	18.0	8.7	9.1	3.1	4.4	4.0	9.3	7.7	6.5	8.0	6.1
32	(8.6)	(11.7)	(9.5)	(7.1)	(6.3)	(6.0)	(11.0)	(7.0)	(9.6)	(8.0)	(6.9)	(8.3)
33	(4.2)	(4.3)	(8.2)	(9.2)	(8.3)	(7.5)	(9.9)	(7.3)	(7.9)	(11.3)	(13.4)	(8.4)
34	6.8	5.4	7.9	7.9	7.6	7.6	11.1	7.3	10.3	10.8	10.6	6.7
35	6.6	11.7	10.5	7.1	7.1	9.2	13.3	9.8	7.2	3.9	5.3	8.3
36	14.5	7.2	8.4	7.6	8.0	6.0	6.8	7.1	5.8	11.4	8.4	8.8
37	9.4	7.4	8.6	7.3	10.0	6.8	7.7	6.1	9.4	7.5	10.1	9.7
38	12.7	6.3	6.5	6.9	7.6	5.2	9.4	8.3	10.8	9.5	11.3	5.5
39	5.9	5.8	5.9	4.8	10.4	8.3	6.8	10.2	12.9	9.8	12.1	7.1
40	10.5	8.2	14.7	6.7	8.2	6.9	5.8	8.0	10.1	6.3	7.4	7.2
Mean	9.6	8.1	8.3	8.2	7.9	6.6	8.1	8.4	8.7	8.9	9.1	8.1

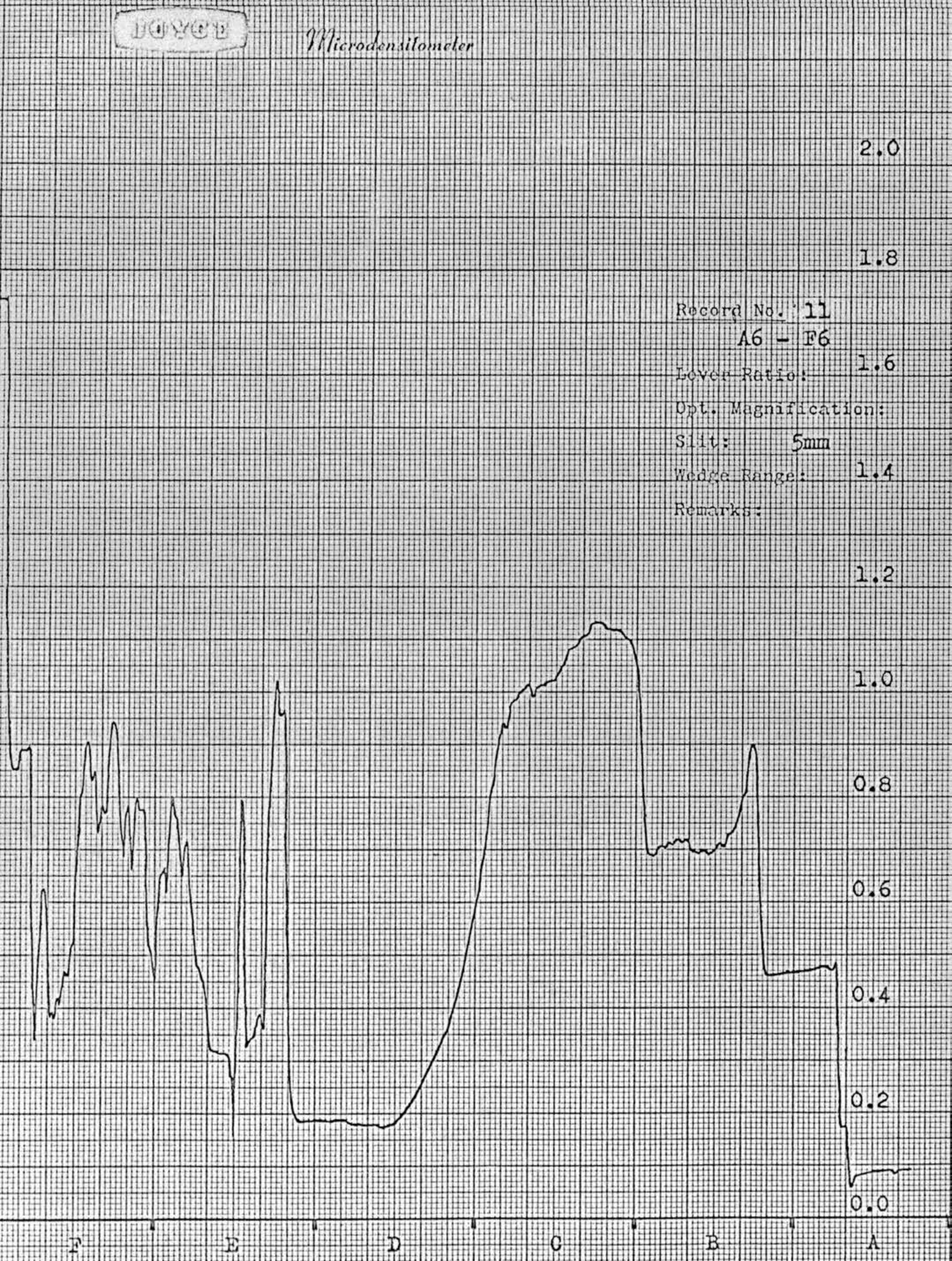
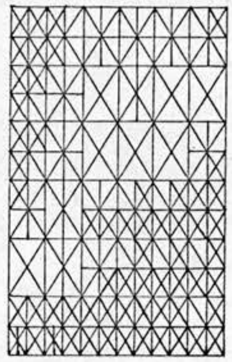


Fig. 43. Microdensitometer Recording of Density, Display 11, Sectors A6 to F6.

1.6	1.2	08	08	08	1.0
1.4	08	0.4	06	0.4	0.4
1.4	08	04	04	04	1.0
1.0	06	1.2	1.3	1.4	1.5
0.4	06	1.0	1.4	1.4	1.4
1.7	1.7	1.6	1.6	1.6	1.4

Density



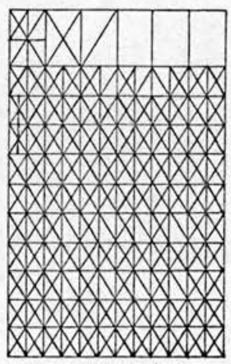
Density
Graphical
DISPLAY 4.

.0	.86	.9	.9	.9	.9
.0	.92	.9	.93	.65	.95
.87	.97	.91	.58	.5	.95
.95	.9	.97	.96	.86	.67
.9	.95	.95	.9	.78	.8
.95	.0	.96	.95	.0	.92

Luminance
Contrast

1.0	04	02	.0	.0	.0
1.8	1.7	1.4	1.4	1.4	1.6
1.8	1.6	1.6	1.6	1.5	1.5
1.5	1.4	1.3	1.3	1.4	1.5
1.5	1.4	1.4	1.4	1.4	1.6
1.6	1.6	1.6	1.6	1.6	1.6

Density



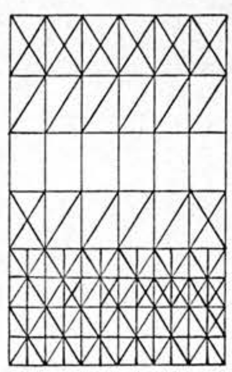
Density
Graphical
DISPLAY 6.

.73	.93	.87	.0	.0	.0
.93	.93	.93	.93	.93	.93
.0	.0	.87	.87	.0	.0
.87	.87	.87	.87	.87	.87
.9	.9	.9	.9	.87	.87
.67	.67	.67	.67	.67	.67

Luminance
Contrast

0.4	0.4	0.4	0.4	0.4	0.4
0.2	0.2	0.2	0.2	0.2	0.2
.0	.0	.0	.0	.0	.0
0.4	0.2	0.2	0.2	0.2	0.4
0.8	1.0	1.0	1.0	1.2	1.2
0.8	0.8	0.8	0.8	0.8	1.0

Density



Density
Graphical
DISPLAY 7.

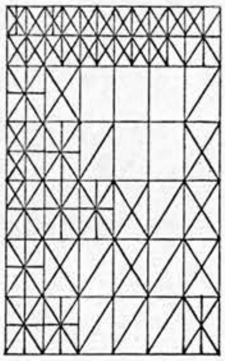
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
.88	.9	.9	.9	.9	.88
.93	.98	.99	.99	.99	.93
.93	.95	.95	.95	.93	.93

Luminance
Contrast

Fig. 44. Photometric Analysis.
Displays 4, 6, 7.

1.8	1.8	1.5	1.6	1.4	1.0
0.8	0.4	.0	.0	.0	0.2
1.1	0.7	0.2	.0	.0	0.4
1.0	0.7	0.7	0.4	0.2	0.4
0.8	0.4	0.2	0.4	0.2	0.4
0.8	0.8	0.2	0.2	0.2	0.6

Density



Density Graphical

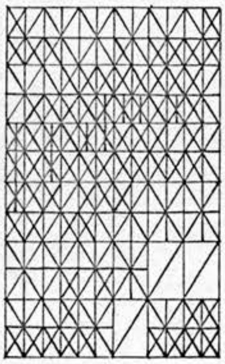
DISPLAY 8.

.0	.0	.0	.97	.97	.97
.95	.98	.4	.0	.0	.97
.55	.75	.9	.33	.0	.6
.94	.93	.67	.67	.88	.96
.87	.7	.6	.75	.75	.94
.88	.95	.7	.67	.7	.92

Luminance Contrast

1.4	0.9	0.8	1.0	1.1	1.3
1.0	1.4	1.7	1.9	1.7	1.2
2.0	2.0	1.8	1.7	1.3	1.1
1.8	1.2	1.4	1.0	0.8	0.8
0.7	1.0	0.9	0.7	0.2	0.2
1.2	1.3	1.0	0.2	1.2	1.6

Density



Density Graphical

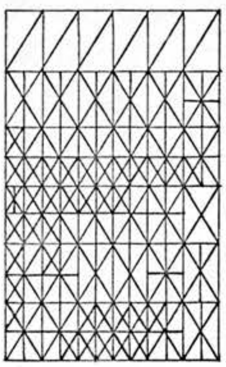
DISPLAY 9.

.0	.8	.83	.83	.83	.67
.9	.9	.9	.9	.5	.0
.5	.5	.5	.5	.83	.6
.96	.97	.8	.8	.6	.76
.83	.8	.17	.52	.52	.84
.0	.0	.5	.25	.93	.89

Luminance Contrast

0.2	0.2	0.2	0.2	0.2	0.2
0.6	0.6	0.6	0.6	0.6	0.7
1.4	1.1	1.1	1.1	1.1	1.0
1.7	1.3	1.1	1.0	0.7	0.3
1.1	1.0	0.6	0.6	0.7	0.5
1.0	1.0	1.5	1.6	0.9	0.7

Density



Density Graphical

DISPLAY 11.

.0	.0	.33	.44	.5	.33
.6	.17	.17	.17	.2	.25
.8	.8	.67	.5	.5	.78
.5	.9	.8	.84	.84	.52
.95	.95	.91	.87	.9	.83
.95	.93	.98	.97	.95	.93

Luminance Contrast

Fig. 44. Continued.
Photometric Analysis.
Displays 8, 9, 11.

1.6	1.2	0.8	0.8	0.8	1.0
1.4	0.8	0.4	0.6	0.4	0.4
1.4	0.8	0.4	0.4	0.4	1.0
1.0	0.6	1.2	1.3	1.4	1.5
0.4	0.6	1.0	1.4	1.4	1.4
1.7	1.7	1.6	1.6	1.6	1.4

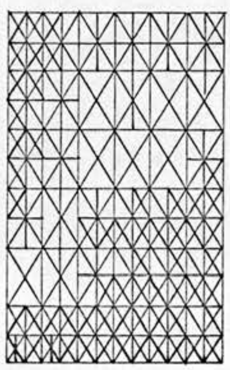
Density

1 1	1 7	1 10	1 10	1 10	1 10
1 1	2 25	3 30	2 30	7 20	1 20
2 15	2 60	7 80	25 60	25 50	2 40
5 100	5 50	3 100	2 50	1 7	1 3
5 50	5 100	5 100	2 20	2 9	1 5
1 20	1 1	1 25	1 20	1 1	1 12

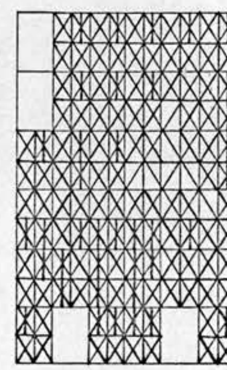
Range of
Photometer
Readings

.0	.86	.9	.9	.9	.9
.0	.92	.9	.93	.65	.95
.87	.97	.91	.58	.5	.95
.95	.9	.97	.96	.86	.67
.9	.95	.95	.9	.78	.8
.95	.0	.96	.95	.0	.92

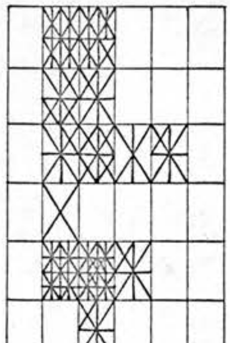
Luminance
Contrast



Density
Graphical

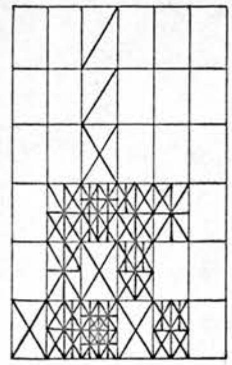


Luminance
Contrast
Graphical



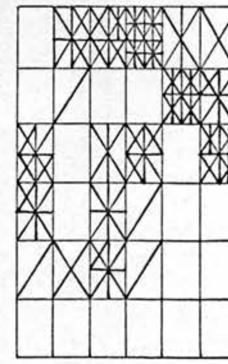
Percentage
Fixations
in each
Sector

SUBJECT 24.



Percentage
Fixations
in each
Sector

SUBJECT 23.



Percentage
Fixations
in each
Sector

SUBJECT 9.

Fig. 45. Photometric Analysis compared with Sector Analysis of Percentage Unit Eye Fixations. Display 4.

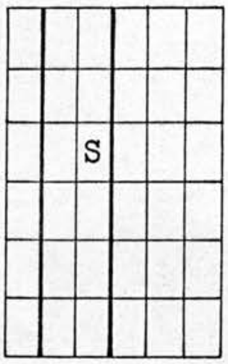
In Display 4 the representation of the spiral stair coincided with twelve sectors or 33.3% of the display, Fig. 46(a). The number of unit fixations in the stair sectors for each subject, and the percentage of unit fixations in these sectors to the total unit fixations, is given in Table XXIII. From this table it is seen that there are fifteen subjects with percentages greater than 66.7% and twenty-nine subjects with percentages greater than 50%. The percentages for subjects 8, 9, 19 and 30 are the lowest in the group of forty subjects and are the closest to 33.3%. Subjects 8, 9 and 30 indicated a subjective response of barrier in the display, subject 19 an inappropriate classification to the path-barrier polarity. The remaining thirty-six subjects indicated that the display represented a path, Tables XVIII and XXIII.

The stair in Display 6 is represented by thirty sectors, Fig. 46(b). The remaining six sectors are referred to as distant sectors. The number of unit fixations occuring in these sectors was obtained for all subjects and a statistical analysis of percentage unit fixations in distant sectors is given later in Table XXXVII. The eye fixation sequence and sector analysis for subjects 13, 19, 23 and 25 are given in Fig. 47.

Analysis of Eye Fixations

$\frac{S}{T}$ percent

Unit Fixations in Stair Sectors S
Total Unit Fixations T

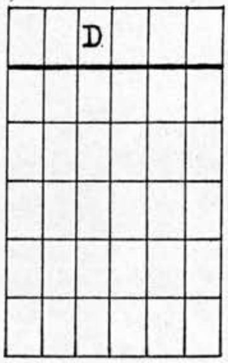


(a) Display 4.

Analysis of Eye Fixations

$\frac{D}{T}$ percent

Unit Fixations in Distant Sectors D
Total Unit Fixations T

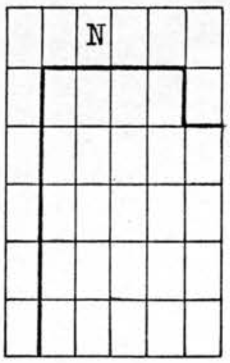


(b) Display 6.

Analysis of Eye Fixations

$\frac{N}{T}$ percent

Unit Fixations in Near Sectors N
Total Unit Fixations.T

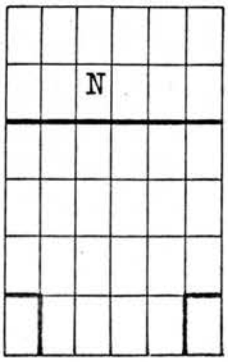


(c) Display 8.

Analysis of Eye Fixations

$\frac{N}{T}$ percent

Unit Fixations in Near Sectors N
Total Unit Fixations T

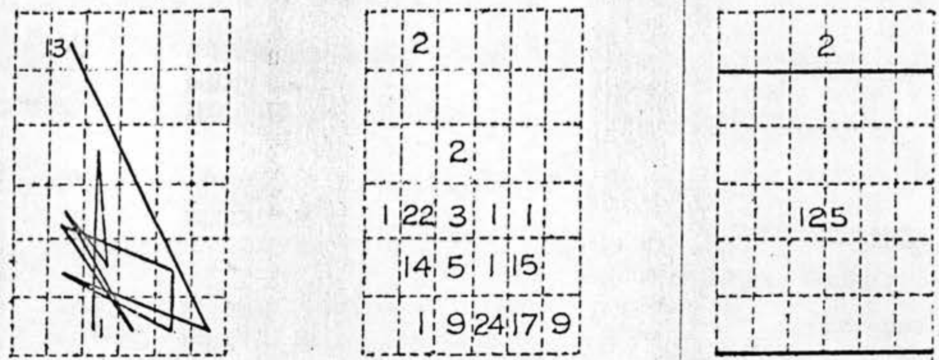


(d) Display 11.

Fig. 46. Graphical Representation of Displays 4, 6, 8 and 11.

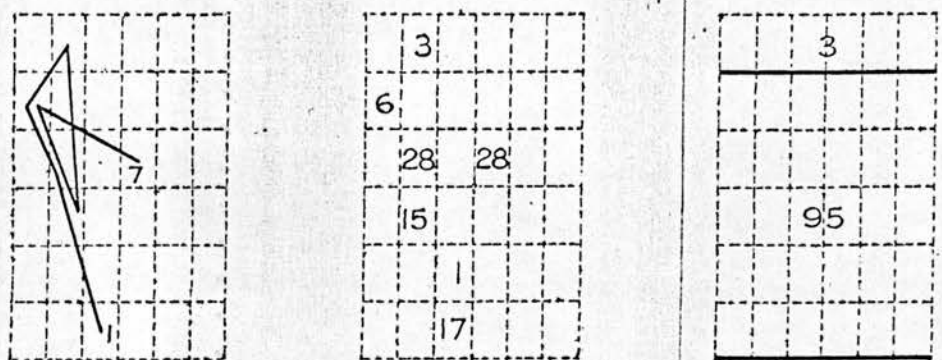
Table XXIII. Percentage Unit Fixations in Stair Sectors. Display 4.

Subject	Stair	Total	%age	Subjective Response
1	212	513	41.3	Move through, Dominating, Path
2	108	250	43.2	Linger, Command, Path
3	410	621	66.0	Move through, Command, Path
4	56	95	58.9	Linger, Command, Path
5	570	779	73.2	Linger, Dominating, Path
6	163	236	69.1	Move through, Inapprop, Path
7	39	73	53.4	Linger, Dominating, Path
8	31	91	34.0	Move through, Dominating, Barrier
9	72	240	30.0	Linger, Command, Barrier
10	263	448	58.7	Linger, Dominating, Path
11	260	362	71.8	Move through, Command, Path
12	278	472	58.9	Move through, Dominating, Path
13	126	209	60.3	Move through, Dominating, Path
14	83	189	43.9	Move through, Inapprop, Path
15	59	84	70.2	Move through, Command, Path
16	485	694	69.9	Linger, Dominating, Path
17	334	540	61.9	Move through, Command, Path
18	65	89	73.0	Move through, Dominating, Path
19	141	438	32.2	Move through, Command, Inapprop
20	45	84	53.6	Move through, Inapprop, Path
21	234	477	49.1	Move through, Command, Path
22	79	94	84.0	Move through, Dominating, Path
23	85	137	62.0	Move through, Inapprop, Path
24	136	155	89.7	Move through, Dominating, Path
25	96	129	74.4	Linger, Dominating, Path
26	66	103	64.1	Move through, Dominating, Path
27	74	77	96.1	Linger, Dominating, Path
28	161	249	64.7	Move through, Command, Path
29	95	189	50.2	Linger, Dominating, Path
30	92	482	19.1	Linger, Dominating, Barrier
31	174	255	68.2	Move through, Dominating, Path
32	122	294	41.5	Move through, Command, Path
33	273	400	68.3	Move through, Dominating, Path
34	574	720	79.7	Move through, Command, Path
35	135	211	64.0	Linger, Command, Path
36	170	370	46.0	Move through, Dominating, Path
37	51	71	71.8	Linger, Dominating, Path
38	167	317	52.7	Linger, Dominating, Path
39	38	91	41.8	Linger, Dominating, Path
40	33	37	89.2	Linger, Command, Path



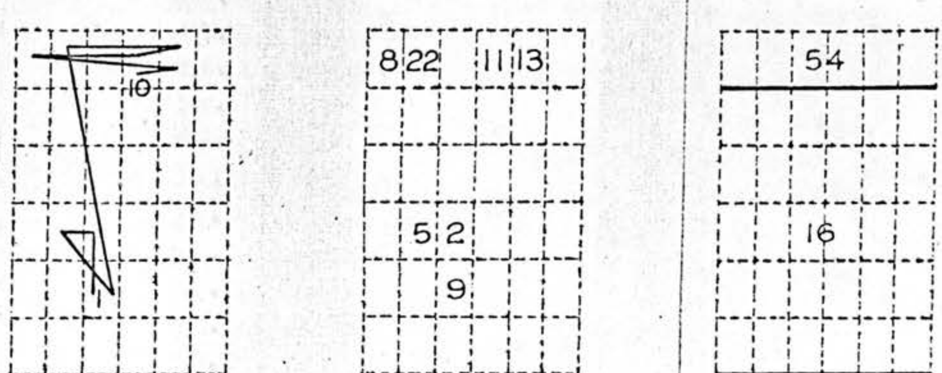
Total fixations 13 — Total unit fixations 127

23. Move through, Command, Path. $\frac{D}{T}$ = 2.6



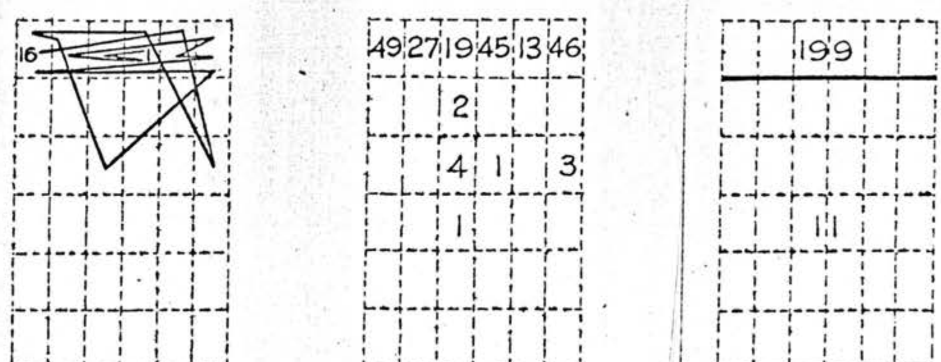
Total fixations 7 — Total unit fixations 98

13. Move through, Command, Path. $\frac{D}{T}$ = 3.1



Total fixations 10 — Total unit fixations 70

25. Move through, Dominating, Path. $\frac{D}{T}$ = 77.1



Total fixations 16 — Total unit fixations 210

19. Move through, Dominating, Path. $\frac{D}{T}$ = 94.8

Fig. 47. Analysis of Eye Fixations, Display 6.

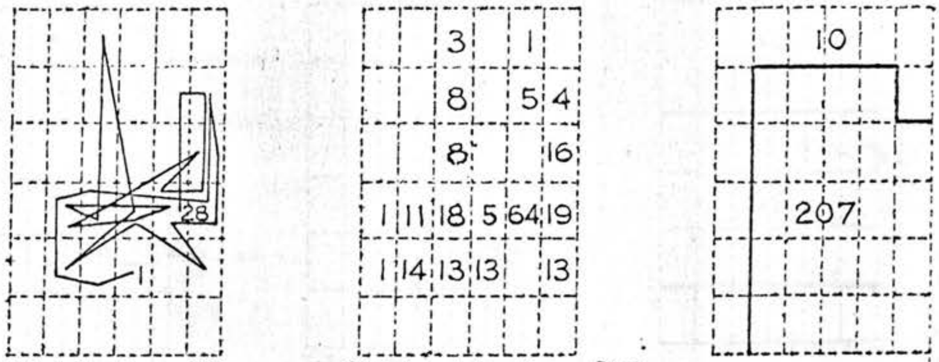
The stereoscopic projection of Display 8 clearly represented the scaffold details to the side of the ramp and the overhead shell vault as near objects. This is illustrated graphically in Fig. 46(c). The eye fixation analysis and percentage fixations in near sectors to total sectors for subjects 5, 9, 13 and 18 are given in Fig. 48.

The graphical representation of near sectors in Display 11 is shown in Fig. 46(d). A statistical analysis of percentage unit fixations in near sectors is given later in Table XXXVIII. The eye fixation analysis for subjects 3, 16, 27 and 30 is given in Fig. 49.

The analysis of eye fixations to the twelve displays is illustrated and discussed in Chapter XVII.

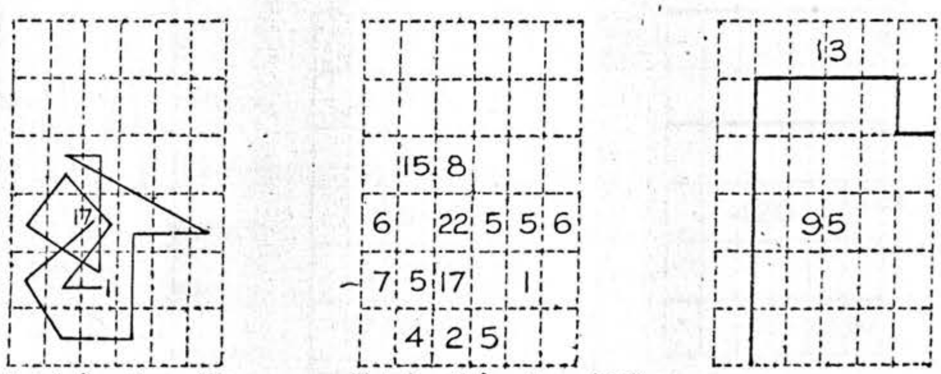
The results of the Sixteen Personality Factor Questionaire were ranked for statistical analyses. A personality factor profile for each subject was obtained from sten scores, Table XXIV. Profiles for subjects 10 and 35 are illustrated in Fig. 50.

A creativity specification was given in Table XI. The weighted sten scores for the factors isolated in the creativity specification are given



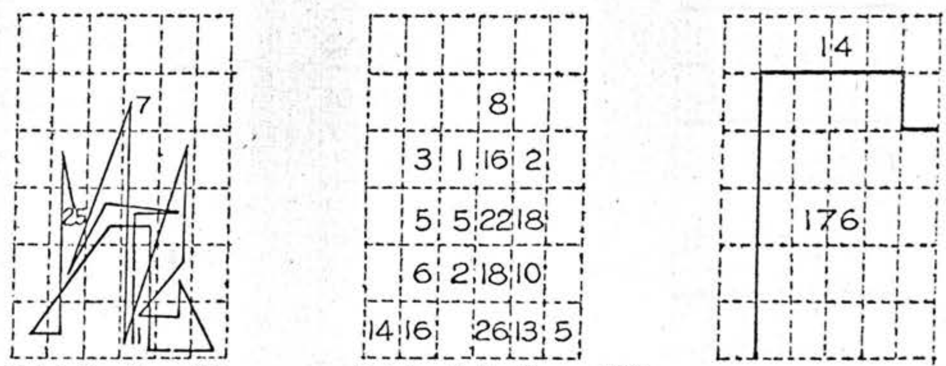
Total fixations 28 | Total unit fixations 217

9. Move through, Command, Path. $\frac{N}{T}$ = 4.6



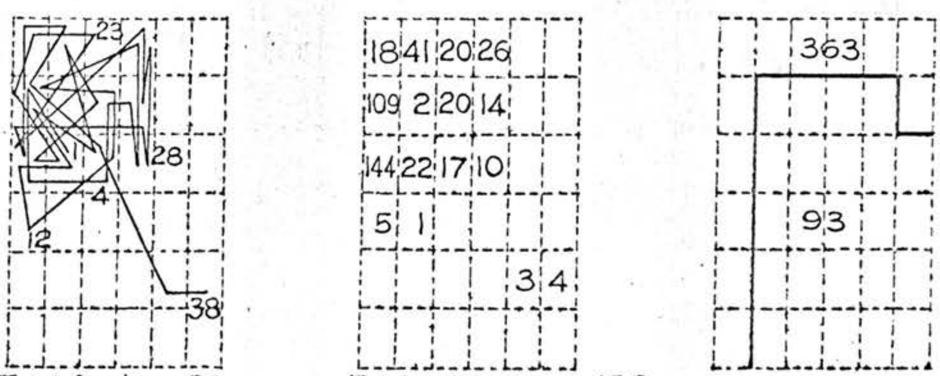
Total fixations 17 | Total unit fixations 108

18. Move through, Command, Path. $\frac{N}{T}$ = 12.0



Total fixations 25 | Total unit fixations 190

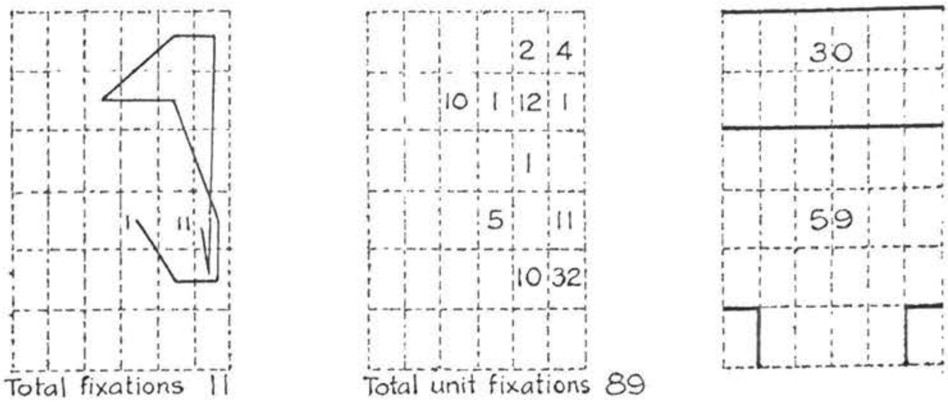
13. Move through, Dominating, Path. $\frac{N}{T}$ = 7.4



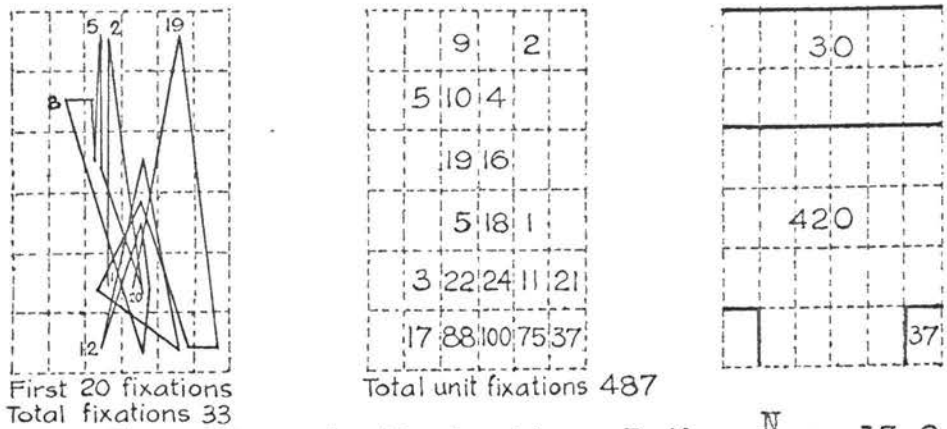
Total fixations 38 | Total unit fixations 456

5. Linger, Command, Path. $\frac{N}{T}$ = 79.6

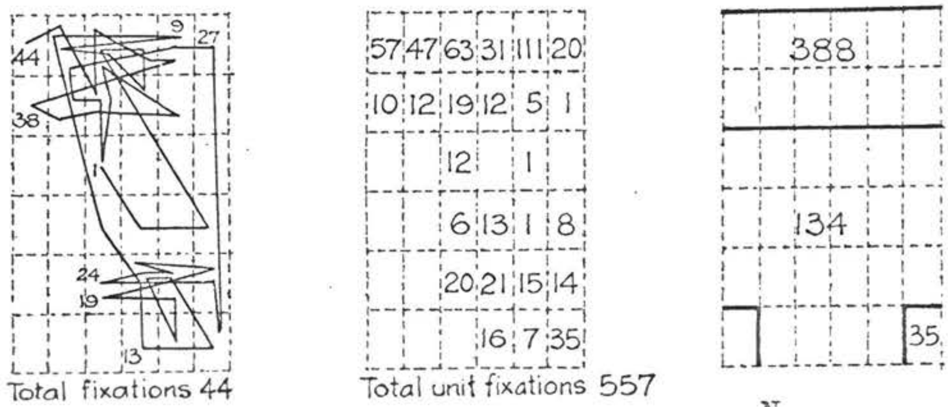
Fig. 48. Analysis of Eye Fixations, Display 8.



27. Move through, Dominating, Path. $\frac{N}{T}$ = 33.7



30. Move through, Dominating, Path. $\frac{N}{T}$ = 13.8



3. Linger, Dominating, Path. $\frac{N}{T}$ = 76.0

16. Linger, Dominating, Path. $\frac{N}{T}$ = 61.6

Fig. 49. Analysis of Eye Fixations, Display 11.

Table XXIV. Sten Scores.
Personality Factors.

Subject	A	B	C	E	F	G	H	I	L	M	N	O	Q_1	Q_2	Q_3	Q_4
1	1	10	5	9	5	4	6	6	8	6	5	5	4	7	6	5
2	2	9	6	9	3	8	5	8	4	7	10	8	10	8	10	6
3	4	9	2	8	7	8	6	7	3	10	6	7	6	7	4	5
4	2	9	5	5	4	5	4	8	6	6	4	7	10	5	3	7
5	1	9	4	6	5	4	5	4	7	6	6	10	5	3	6	6
6	6	10	7	8	7	4	6	6	5	9	7	5	6	6	3	7
7	6	7	6	6	6	1	6	3	9	4	7	2	8	8	7	3
8	4	10	2	5	7	4	5	7	10	10	6	10	8	5	5	10
9	6	9	3	7	6	4	5	3	9	8	4	9	8	3	4	9
10	1	10	2	8	3	4	3	10	6	8	4	8	8	10	5	6
11	2	9	3	5	5	2	3	9	9	9	3	8	9	8	1	10
12	6	10	3	6	8	2	5	6	5	10	4	8	7	5	5	9
13	4	9	4	5	10	2	3	8	3	10	6	9	7	7	1	10
14	3	8	5	7	6	2	5	5	10	10	7	7	10	7	3	9
15	4	10	5	8	9	1	6	4	6	9	7	3	6	4	5	6
16	5	10	5	8	5	4	5	7	2	9	5	7	10	7	5	5
17	7	9	2	8	6	2	3	6	6	10	7	8	6	5	1	10
18	5	8	4	9	6	5	7	7	8	4	7	6	3	4	4	7
19	5	9	5	8	7	4	5	7	4	9	7	5	8	7	3	5
20	6	10	5	6	3	1	4	10	2	9	6	7	7	9	3	5
21	5	7	4	7	8	5	5	1	7	3	6	6	9	7	3	4
22	5	10	7	5	7	10	7	5	5	8	9	3	8	6	6	2
23	3	10	4	6	5	4	4	4	6	8	4	7	8	8	5	6
24	5	10	4	10	7	4	4	2	4	6	6	8	4	10	2	7
25	4	8	4	6	4	6	4	5	6	9	5	9	5	8	1	10
26	4	8	7	7	6	5	4	8	6	10	7	5	8	7	1	7
27	2	10	7	6	6	10	6	7	2	6	4	6	7	6	6	7
28	2	10	3	8	5	5	5	4	8	7	4	7	3	3	5	8
29	4	6	5	1	9	1	8	8	7	10	2	6	7	7	1	7
30	3	9	5	5	5	3	4	10	5	9	3	6	7	6	4	7
31	5	7	4	5	3	5	6	6	7	6	7	4	5	7	6	4
32	6	9	3	5	7	5	4	7	6	7	6	7	6	5	4	8
33	4	7	4	5	9	2	7	6	7	6	3	6	2	6	2	9
34	4	7	4	9	5	2	7	5	7	10	8	5	5	2	1	9
35	3	3	5	8	7	3	4	5	7	5	1	8	6	4	6	7
36	5	9	5	5	4	6	4	3	8	7	2	3	5	7	9	6
37	5	8	5	6	5	5	6	4	4	7	2	5	6	7	5	6
38	7	9	6	5	9	6	5	8	6	10	7	6	6	7	3	6
39	5	9	5	7	9	1	6	4	8	3	7	5	4	5	1	9
40	6	10	3	9	8	2	6	4	9	8	4	7	5	1	3	8

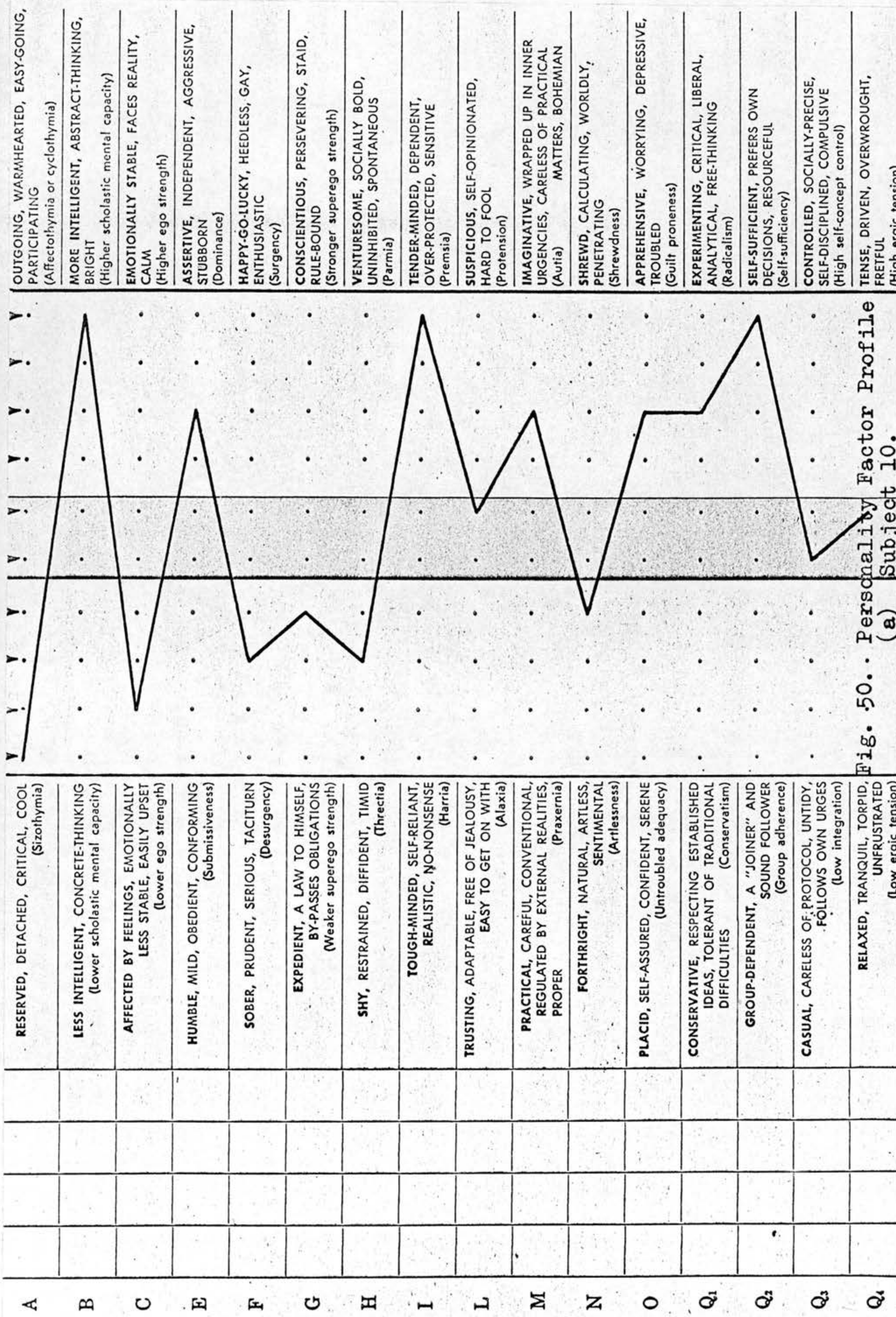


Fig. 50. Personality Factor Profile (a) Subject 10.

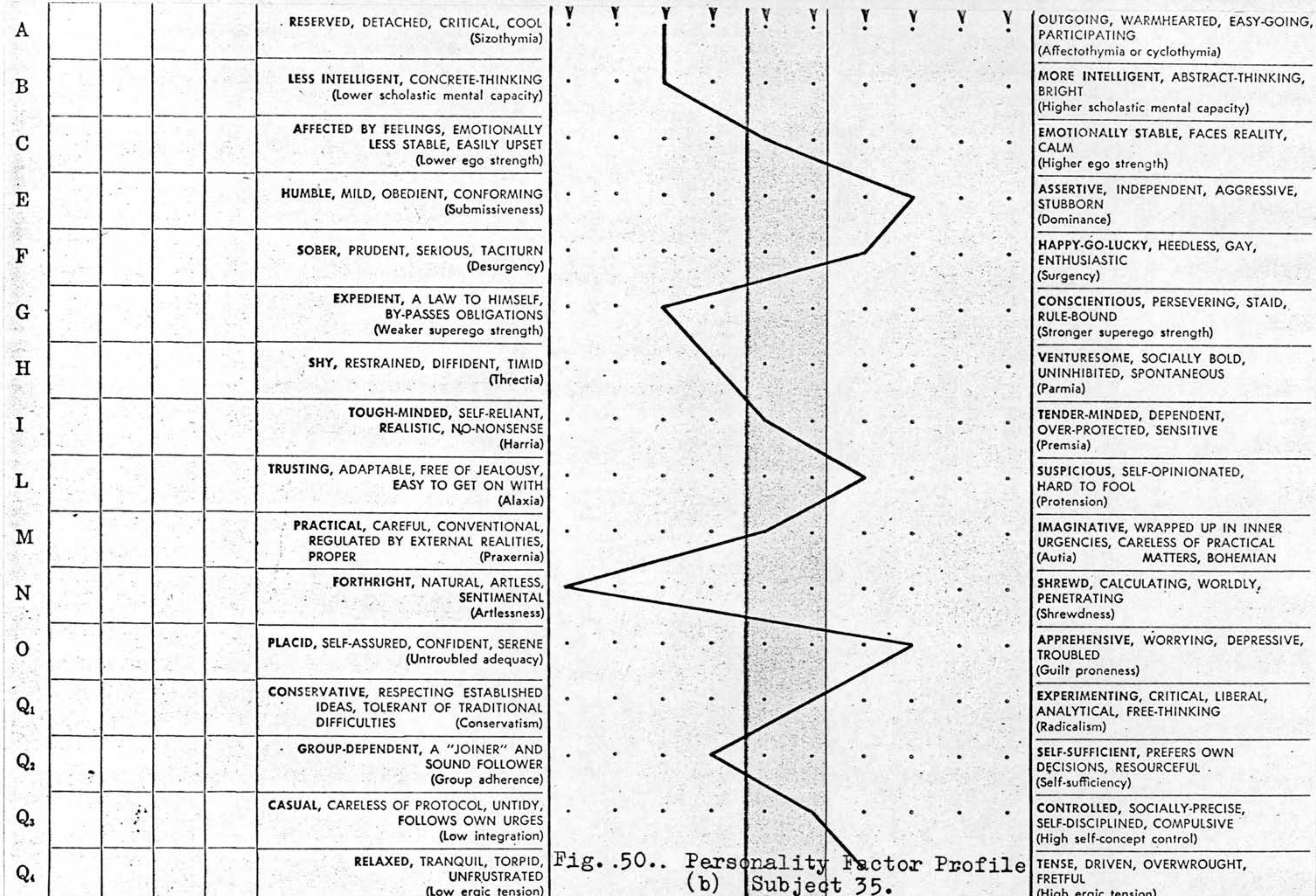


Fig. 50.. Personality Factor Profile (b) Subject 35.

in Table XXV. It is seen from this table that the range of creativity scores was from 76 for subject 39 to 130 for subject 10. The average for the forty subjects was 96.8. Drevdahl (1958), Jones (1963), Cattell (1963) and others have shown that the average creativity score for the general population is approximately 82.5.

Three special tests in the recording of eye fixations and subjective responses were described in Chapter XIII.

Subject 9, in addition to participation in the main study, viewed the series of stereoscopic slides on two further occasions. Each occasion was separated in time by more than three weeks. The subjective responses are given in Table XXVI. From this table it is seen that for Displays 1, 5, 6, 7, 8 and 10 the recording of responses on the three occasions was identical. In Displays 3, 4, 9 and 12 there was one variation in the recording of subjective responses, and in Displays 2 and 11 there was variation in two or more responses. The stimulation responses for the three occasions are given in Table XXVII. In Displays 1, 3, 5, 11 and 12 the responses were identical for the intensity and direction of stimulation. There were eight

Table XXV. Creativity Scores.
For Creativity Specification,
Table XI.

Subject	Weighted Score										Total
	A-	B	E	F-	H	I	M	N-	Q1	Q2	
1	20	20	9	12	6	12	6	6	4	14	109
2	18	18	9	16	5	16	7	1	10	16	116
3	14	18	8	8	6	14	10	5	6	14	103
4	18	18	5	14	4	16	6	7	10	10	108
5	20	18	6	12	5	8	6	5	5	6	91
6	10	20	8	8	6	12	9	4	6	12	95
7	10	14	6	10	6	6	4	4	8	16	84
8	14	20	5	8	5	14	10	5	8	10	99
9	10	18	7	10	5	6	8	7	8	6	85
10	20	20	8	16	3	20	8	7	8	20	130
11	18	18	5	12	3	18	9	8	9	16	116
12	10	20	6	6	5	12	10	7	7	10	93
13	14	18	5	16	3	16	10	5	7	14	108
14	16	16	7	10	5	10	10	4	10	14	102
15	14	20	8	4	6	8	9	4	6	8	87
16	12	20	8	12	5	14	9	6	10	14	110
17	8	18	8	10	3	12	10	4	6	10	89
18	12	16	9	10	7	14	4	4	3	8	87
19	12	18	8	8	5	14	9	4	8	14	100
20	10	20	6	16	4	20	9	5	7	18	115
21	12	14	7	6	5	2	3	5	9	14	77
22	12	20	5	8	7	10	8	2	8	12	92
23	16	20	6	12	4	8	8	7	8	16	105
24	12	20	10	8	4	4	6	5	4	20	93
25	14	16	6	14	4	10	9	6	5	16	100
26	14	16	7	10	4	16	10	4	8	14	103
27	18	20	6	10	6	14	6	7	7	12	106
28	18	20	8	12	5	8	7	7	3	6	94
29	14	12	1	4	8	16	10	9	7	14	95
30	16	18	5	12	4	20	9	8	7	12	111
31	12	14	5	16	6	12	6	4	5	14	94
32	10	18	5	8	4	14	7	5	6	10	87
33	14	14	5	4	7	12	6	8	2	12	84
34	14	14	9	12	7	10	10	3	5	4	88
35	16	6	8	8	4	10	5	10	6	8	81
36	12	18	5	14	4	6	7	9	5	14	94
37	12	16	6	12	6	8	7	9	6	14	96
38	8	18	5	4	5	16	10	4	6	14	90
39	12	18	7	4	6	8	3	4	4	10	76
40	10	20	9	6	6	8	8	7	5	2	81

Table XXVI. Subjective Responses, Subject 9.
Repetition of Displays.

1 Initial Viewing 2 Second Viewing 3 Third Viewing

	DISPLAY											
	1	2	3	4	5	6	7	8	9	10	11	12
Linger.		1 2 3	2	1 2 3	1 2 3		1 2 3		1 2 3		1 2	1 2 3
Move through.	1 2 3		1 3			1 2 3		1 2 3		1 2 3	3	
Inapprop.												

	1	2	3	4	5	6	7	8	9	10	11	12
Dominating.		1 3		2 3	1 2 3				1		1	1 2 3
Command.	1 2 3	2	1 2 3	1		1 2 3	1 2 3	1 2 3	2 3	1 2 3	2 3	
Inapprop.												

	1	2	3	4	5	6	7	8	9	10	11	12
Path.	1 2 3	2	1 2 3			1 2 3		1 2 3		1 2 3	1 3	1
Barrier.		1 3		1 2 3	1 2 3		1 2 3		1 2 3		2	2 3
Inapprop.												

Table XXVII. Stimulation Responses, Subject 9.
Repetition of Displays.

1 Initial Viewing   2 Second Viewing   3 Third Viewing

DISPLAY

	1	2	3	4	5	6	7	8	9	10	11	12
very interesting			1 2 3		1 2 3			1 2 3	1		1 2 3	
interesting	1 2 3			2 3			2 3		2	1 3	1 2 3	I 2 3
neutral		1 2 3		1			1		3	2		
dull						1 2 3						
very dull												

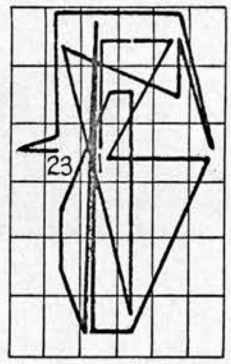
very fine			1 2 3		1 2 3			2 3			1 2 3	1 2 3
fine		2 3					2	1	1 3			
neutral	1 2 3	1		1 2 3		2	1 3		2	1 3		
poor						1 3				2		
very poor												

displays with identical recording of intensity of stimulation.

The lack of agreement of subjective responses to the repetitive viewing of Display 2 can be compared to the lack of agreement between subjects for this display. This is discussed later in Chapter XVII.

The eye fixation sequences and sector analyses for Display 5 are given in Fig. 51. It is seen from Tables XXVI and XXVII that, for this display, all subjective and stimulation responses were identically recorded for the three occasions.

In the initial viewing of Display 11 the percentage of unit fixations in near sectors to total unit fixations was 46.0. On the second viewing the percentage was 25.3, and on the third viewing 8.7. The subjective responses for the first occasion were linger, dominating, path; on the second occasion linger, command, barrier; and finally move through, command, path. In Chapter XV a suggested relationship between the percentages of unit fixations in the near sectors of this display and the subjective responses of the forty subjects is tested statistically and discussed.



Total fixations 23

	26	19	7	11	
		3	19	9	
4	5	24	1	1	14
	3				
	3	1	1		
		29	18	1	

Total unit fixations 199

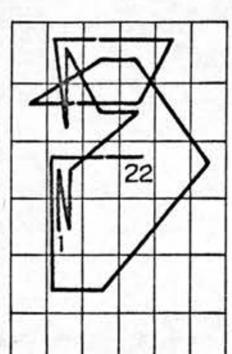
Initial Viewing.

First 20 fixations
Total fixations 57

		5	34		
13	8	11	18	5	
22	41	15	10	37	
24	105	21	5	6	
39	28	11	8		
53	2	14			

Total unit fixations 535

Second Viewing.



Total fixations 22

	110	66	19	11	
9	42	17	22		
	68	11	10		51
	27				1
	12	4			

Total unit fixations 480

Third Viewing.

Fig. 51. Repetition of Display 5.
Analysis of Eye Fixations.
Subject 9.

There is variation in the intensity of stimulation responses to Display 9. On the first occasion of viewing the display was classified as very interesting; on the second, interesting; and on the third, neutral. The analysis of eye fixations on each occasion is similar with fixations occurring throughout the display. The recording of viewing time on the three occasions, Table XXVIII, gives no indication for variation in the intensity of stimulation.

Table XXVIII. Viewing Time in Unit Fixations. Repetition of Displays, Subject 9.

	DISPLAY												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
First	510	260	341	240	199	204	256	217	194	179	235	175	3010
Second	234	468	417	424	535	255	423	571	426	485	656	326	5220
Third	324	425	706	565	480	360	469	411	319	359	492	372	5282

The analysis of eye fixations in the special study of convergence has shown that, for these recordings, the fixations occurring in the near sectors of Displays 8 and 11 were fixations of near objects. The measurement of differential horizontal parallax from the recordings of the fixations of the left and right eye could be discriminated only for near and distant objects. The accuracy of the recording of electro-oculography in this study was discussed in Chapter XIII. The study of convergence served only to assure that, for subjects in the main study, eye fixations recorded within an area of the display simplified as a near sector were most likely convergent fixations on a near object.

In the third special study, two subjects viewed the series of stereoscopic slides and a stereoscopic motion picture of the same spatial sequences. The subjects were architects who had not visited the Sydney Opera House nor viewed slides of the spaces within the building. The subjects viewed the stereoscopic motion picture immediately prior to viewing the series of slides. A questionaire of the importance of each display relative to the stereo-scopic motion picture was given to these subjects. The questionaire and results are given in Table XXIX.

Table XXIX. Results.
Questionaire of the Importance of Displays
Relative to the Stereoscopic Motion Picture.

Figures indicate the responses of Subjects 41 and 42.

You have just viewed a motion picture of a spatial sequence.

A series of 12 slides of the same sequence will now be projected. Each display will be projected for 10 seconds. Following each display please indicate the importance you attach to the display as part of the spatial sequence as you recall it in the motion picture projection.

DISPLAY

	1	2	3	4	5	6	7	8	9	10	11	12
essential	41		42				41 42		41 42		42	
important		41		41 42		41		42		41	41	
neutral	42		41		41	42		41		42		
not important		42			42							41 42
irrelevant												

From your appreciation of the spatial sequence shown in the motion picture, would you consider the series of slides <u>appropriate</u>/inappropriate for recording the sequence.
41, 42.

CORRELATIONS

XV. STATISTICAL ANALYSIS

A graphical illustration of the intensity of stimulation score and the direction of stimulation score for the forty subjects was given in Fig. 42. From this figure it is seen that the resultant plotting of intensity and direction for each display approximates to a line 45° to the axes of the graph.

For each subject the positive intensity scores of the twelve displays have been added together to provide a total positive intensity score. A total positive direction score for each subject has similarly been obtained from the individual direction scores. Responses of positive intensity and direction have been weighted as described in Chapter XIV. Neutral and negative responses of stimulation have been ignored in this analysis. The total positive intensity scores and the total positive direction scores of the forty subjects are listed in Table XXX and the Spearman Correlation test has been applied to the ranks of these scores.

Table XXX. Positive Intensity and Direction Scores For each Subject.

Subject	Positive Intensity Score	Rank	Positive Direction Score	Rank	D	D^2
1	14	24.5	6	8	16.5	272.25
2	7	2.5	3	2.5	-	
3	16	31.5	10	24.5	7	49
4	16	31.5	10	24.5	7	49
5	16	31.5	11	29	2.5	6.25
6	12	16.5	8	16.5	-	
7	8	4.5	5	5	- 0.5	0.25
8	15	28	15	36.5	- 8.5	72.25
9	13	20.5	10	24.5	- 4	16
10	17	35	15	36.5	- 1.5	2.25
11	19	38	12	30.5	7.5	56.25
12	14	24.5	9	20.5	4	16
13	11	12.5	10	24.5	-12	144
14	13	20.5	10	24.5	- 4	16
15	11	12.5	7	11.5	1	1
16	21	40	16	39	1	1
17	16	31.5	14	33	- 1.5	2.25
18	15	28	14	33	- 5	25
19	20	39	19	40	- 1	1
20	13	20.5	7	11.5	9	81
21	8	4.5	5	5	- 0.5	0.25
22	11	12.5	8	16.5	- 4	16
23	12	16.5	8	16.5	-	
24	10	9.5	7	11.5	- 2	4
25	12	16.5	8	16.5	-	
26	6	1	2	1	-	
27	17	35	14	33	2	4
28	17	35	15	36.5	- 1.5	2.25
29	9	7	8	16.5	- 9.5	90.25
30	18	37	12	30.5	6.5	42.25
31	15	28	10	24.5	3.5	12.25
32	9	7	8	16.5	- 9.5	90.25
33	13	20.5	9	20.5	-	
34	9	7	6	8	- 1	1
35	7	2.5	3	2.5	-	
36	10	9.5	5	5	4.5	20.25
37	12	16.5	10	24.5	- 8	64
38	14	24.5	15	36.5	-12	144
39	11	12.5	6	8	4.5	20.25
40	14	24.5	7	11.5	13	169
						1490.75

Table XXX. Continued.

Ties	Intensity	Direction	Total
2	3	3	6
3	3	3	6
4	5	2	7
5	-	-	-
6	-	1	1
7	-	1	1

$$T = \tfrac{1}{2} t_2 + 2 t_3 + 5 t_4 + 10 t_5 + 17.5 t_6 + 28 t_7$$

$$= (\tfrac{1}{2} \times 6) + (2 \times 6) + (5 \times 7) + 0 + (17.5 \times 1) + (28)$$

$$= 95.5$$

$$D^2 + T = 1490.75 + 95.5 = 1586.25$$

$$z = \sqrt{n - 1} \left| 1 - \frac{D^2 + T}{(n - n)} \right|$$

$$= \sqrt{40 - 1} \left| 1 - \frac{1586.25}{10660} \right|$$

$$= \sqrt{39} \left| 1 - 0.149 \right|$$

$$= 6.24 \times 0.851$$

$$= 5.31$$ From z table, probability $P < 0.2\%$

Correlation is shown to be statistically significant, ($z = 5.31$; $P < 0.2\%$).

The individual scores of creativity, from the creativity specification, were given in Table XXV. These scores have been ranked and compared with ranks of the total positive intensity score for each subject. The Spearman Correlation test is given in Table XXXI. It is seen that a correlation is probably significant. ($z = 2.46$; $P < 5\%$)

A correlation between ranks of the positive direction scores and creativity was not proven, ($z = 1.85$; $P > 5\%$). Further statistical tests were carried out using the ranks of the creativity scores. These included the comparison of ranks of total inappropriate scores for the forty subjects. Correlations were not proven.

Ranks of the sixteen personality factor scores were compared with the total intensity ranks and total direction ranks. The Spearman Correlation test indicated that correlation between Factor I and positive intensity was probably significant, ($z = 2.17$; $P < 5\%$). There was also probable significance in correlation between Factor I and positive direction ($z = 2.30$; $P < 5\%$). Factor I in part is a measure of sensitivity and it is noted that the sten scores of this factor were multiplied by two in the creativity specification, Tables XI and XXV. The test for correlation between positive direction and ranks of Factor O provided a z of 1.95 ($P \simeq 5\%$). In all other factors correlation was not proven.

Table XXXI. Ranks of Positive Intensity and Creativity.

Subject	Positive Intensity Ranks	Creativity Ranks	D	D^2
1	24.5	34	- 9.5	90.25
2	2.5	38.5	-36	1296
3	31.5	28.5	3	9
4	31.5	32.5	- 1	1
5	31.5	14	17.5	306.25
6	16.5	21.5	- 5	25
7	4.5	5.5	- 1	1
8	28	24	4	16
9	20.5	7	13.5	182.25
10	35	40	- 5	25
11	38	38.5	- 0.5	0.25
12	24.5	16.5	8	64
13	12.5	32.5	-20	400
14	20.5	27	- 6.5	42.25
15	12.5	9	3.5	12.25
16	40	35	5	25
17	31.5	12	19.5	380
18	28	9	19	361
19	39	25.5	13.5	182.25
20	20.5	37	-16.5	272.25
21	4.5	2	2.5	6.25
22	12.5	15	- 2.5	6.25
23	16.5	30	-13.5	182.25
24	9.5	16.5	- 7	49
25	16.5	25.5	- 9	81
26	1	28.5	-27.5	756.25
27	35	31	4	16
28	35	19	16	256
29	7	21.5	-14.5	209.25
30	37	36	1	1
31	28	19	9	81
32	7	9	- 2	4
33	20.5	5.5	15	225
34	7	11	- 4	16
35	2.5	3.5	- 1	1
36	9.5	19	- 9.5	90.25
37	16.5	23	- 6.5	42.25
38	24.5	13	11.5	131.25
39	12.5	1	11.5	131.25
40	24.5	3.5	21	441
				6417.25

$T = 40.5$
$D^2 + T = 6457.75$
$z = 2.46$
$P < 5\%$

The total subjective responses of command for each subject is listed as a score in Table XXXII. From this table there is shown to be probable significance of correlation between ranks of these scores and ranks of Factor E scores ($z = 2.4$; $P < 5\%$). In the bipolar classification of the sixteen personality factors, Table X, a high score of Factor E described dominance of a subject; a low score, submissiveness. A high score of this personality factor would suggest an assertive individual in terms of relationships with other individuals. It is suggested from the above probable correlation that this individual has more frequent responses of being in command of architectural spaces and of his environment generally.

The total viewing time of each subject was given in Table XXI. These figures of total unit fixations have been ranked and compared with ranks of the sixteen personality factors. For each personality factor there was shown to be no probable correlation.

The percentages of unit fixations for the displays were given in Table XXII. For each display subjects were divided into groups from their subjective responses of linger, move through, dominating, command, path and barrier. The Wilcoxon

Table XXXII. Responses of Command and Factor E Scores.

Subject	Responses of Command	Ranks	Factor E Scores	Ranks	D	D^2
1	5	24.5	9	37	-12.5	156
2	8	37	9	37	-	
3	6	30.5	8	30	0.5	0.25
4	7	35	5	7	28	784
5	4	18	6	16.5	1.5	2.25
6	2	5.5	8	30	-24.5	600
7	3	11.5	6	16.5	- 5	25
8	2	5.5	5	7	- 1.5	2.25
9	7	35	7	23	12	144
10	6	30.5	8	30	0.5	0.25
11	4	18	5	7	11	121
12	3	11.5	6	16.5	- 5	25
13	4	18	5	7	11	121
14	0	1	7	23	-22	484
15	10	40	8	30	10	100
16	3	11.5	8	30	-18.5	343
17	5	24.5	8	30	- 5.5	30.25
18	2	5.5	9	37	-21.5	462
19	9	38.5	8	30	8.5	72.25
20	4	18	6	16.5	1.5	2.25
21	2	5.5	7	23	-17.5	306
22	2	5.5	5	7	- 1.5	2.25
23	3	11.5	6	16.5	- 5	25
24	4	18	10	40	-22	484
25	5	24.5	6	16.5	8	64
26	3	11.5	7	23	-11.5	132
27	2	5.5	6	16.5	-11	121
28	7	35	8	30	5	25
29	1	2	1	1	1	1
30	6	30.5	5	7	23.5	551
31	5	24.5	5	7	17.5	306
32	3	11.5	5	7	4.5	20.25
33	4	18	5	7	11	121
34	9	38.5	9	37	1.5	2.25
35	6	30.5	8	30	0.5	0.25
36	5	24.5	5	7	17.5	306
37	5	24.5	6	16.5	8	64
38	4	18	5	7	11	121
39	6	30.5	7	23	7.5	56.25
40	6	30.5	9	37	- 6.5	42.25
						6225.25

$T = 332.5$
$D^2 + T = 6557.75$

$z = 2.4$
$P < 5\%$

Sum of Ranks test has shown that for each display there are no probable correlations between the percentage viewing time and these responses.

The viewing time of the forty subjects for each display has been added together and is listed in Table XXXIII. The total intensity and direction of stimulation scores of the displays, from Table XX, is also given and ranked.

Table XXXIII. Total Viewing Time and Stimulation Scores.

	Viewing Time		Stimulation			
Display	Total	Ranks	Intensity	Ranks	Direction	Ranks
1	11923	9	37	4	15	4.5
2	9446	2	12	2	0	2
3	10746	4	55	9	23	6.5
4	11364	7	52	8	37	9
5	10452	3	24	3	15	4.5
6	8798	1	1	1	-8	1
7	11113	6	42	6	23	6.5
8	11062	5	49	7	31	8
9	11560	8	62	11	48	11
10	12503	11	38	5	14	3
11	11991	10	61	10	47	10
12	(10586)		33		18	

From the listing of viewing times, Table XXI, it is seen that the recordings of six subjects were incomplete for Display 12. This display is omitted from the following statistical analysis.

For the ranks of viewing time and intensity of stimulation, Spearman's $D^2 + T = 100$. A correlation between these ranks is not proven. A correlation between viewing time and the direction of stimulation is also not proven.

It is seen from Table XXXIII that there are substantial differences in ranks for Displays 1 and 10. If these two displays are omitted from this table, the ranks for the nine displays are as shown in Table XXXIV. A comparison of the viewing time and intensity ranks then indicates $D^2 + T = 16$. For the viewing time and direction ranks, $D^2 + T = 6$. Correlation between the ranks in both cases is statistically significant ($P < 1\%$).

Table XXXIV. Total Viewing Time and Stimulation Scores For 9 Displays.

	Viewing Time		Stimulation			
Display	Total	Ranks	Intensity	Ranks	Direction	Ranks
2	9446	2	12	2	0	2
3	10746	4	55	7	23	4.5
4	11364	7	52	6	37	7
5	10452	3	24	3	15	3
6	8798	1	1	1	- 8	1
7	11113	6	42	4	23	4.5
8	11062	5	49	5	31	6
9	11560	8	62	9	48	9
11	11991	9	61	8	47	8

From the combinations of subjective responses to Display 1, Table XVIII, there were thirteen subjects whose response was move through, dominating, path and five subjects whose response was move through, command, path. The stimulation scores for these groups of subjects are given in Table XXXV.

Table XXXV. Stimulation Scores for groups of Subjects. Display 1.

Move thro', dominating, path			Other responses		
Subject	Intensity	Direction	Subject	Intensity	Direction
4	1	- 1	1	0	- 1
5	2	1	2	0	0
8	2	1	3	1	1
10	2	1	6	- 1	- 2
11	2	0	7	0	- 2
13	1	1	12	1	- 1
14	1	1	15	- 1	0
17	2	1	18	1	1
19	2	2	21	1	1
22	1	0	24	0	0
23	1	0	25	0	0
26	0	- 2	27	2	2
39	1	1	29	1	0
	18	9 - 3	30	1	1
			32	1	1
			33	0	- 1
Move through, command, path			34	1	1
9	1	0	35	- 1	0
16	2	2	36	0	0
20	1	0	37	1	0
28	2	2	38	1	1
31	2	1	40	2	2
	8	5		14 - 3	11 - 7

The Wilcoxon Sum of Ranks test for the intensity of stimulation scores is given in Table XXXVI.

Table XXXVI. Intensity of Stimulation for groups of Subjects, Display 1.
Wilcoxon Sum of Ranks Test.

Group A. Responses of Move through, dominating, path and Move through, command, path. (18 subjects)

Group B. Other responses. (22 subjects)

Intensity Scores	A	B	Rank values i	Rank values ii	A Ranks i	A Ranks ii	B Ranks i	B Ranks ii
- 1		BBB	2	39				
0	A	BBBBBBB	7.5	33.5		33.5		
1	AAAAAAAA	BBBBBBBBBB	20.5	20.5		164		
2	AAAAAAAAA	BB	35	6		54		
		Smallest rank total				251.5		

$$R = 251.5$$

$$n_R = n_A = 18$$

$$n_B = 22$$

$$n_R\,(n_A + n_B + 1) - 2R = 235.2$$

$$\sqrt{\frac{n_A \cdot n_B\,(n_A + n_B + 1)}{3}} = 73.6$$

$$z = \frac{n_R\,(n_A + n_B + 1) - 2R}{\sqrt{\frac{n_A \cdot n_B\,(n_A + n_B + 1)}{3}}}$$

$$= 3.2$$

The difference in the intensity of stimulation of the two groups is statistically significant ($P < 1\%$).

A significant difference in the direction of stimulation of these two groups is not proven.

From these results it is seen that there was a statistically significant correlation of greater interest in Display 1 by subjects whose subjective response was move through, dominating, path or move through, command, path than by subjects who responded in a different way.

In Display 10 the intensity of stimulation score of twelve subjects in the groups move through, dominating, path and move through, command, path was 17. The direction of stimulation score was 13. For the twenty-eight subjects who responded to this display in a way other than the above classification the intensity of stimulation score was 21. The direction of stimulation score was 3. The Wilcoxon Sum of Ranks test has shown that the difference in the direction of stimulation scores of these groups was probably significant ($z = 2.4$; $P < 5\%$).

Displays 1 and 10 record the same architectural space but it is viewed from different positions. This will be discussed later in Chapter XVII.

For Display 6 there were twenty-two subjects whose classification of subjective responses was move through, command, path. There were seven subjects in the classification of move through, dominating, path. The percentages of unit fixations in distant sectors to total unit fixations are given in Table XXXVII for the two groups of subjects. The Wilcoxon Sum of Ranks test suggests that the correlation between lower percentages for subjects in the move through, command, path classification is probably significant ($z = 1.99$; $P < 5\%$). A shorter

Table XXXVII. Percentage Unit Fixations in Distant Sectors. Display 6.

$\frac{D}{T}$ %	Move through, Dominating, Path	Move through, Command, Path	Rank Values	A Ranks
0		BBB	28	
1.3		B	26	
2.6		B	25	
3.1		B	24	
8.4		B	23	
15.4		B	22	
20.7		B	21	
31.3		B	20	
36.5		B	19	
41.4	A		18	18
44.9		B	17	
45.6		B	15.5	
46.5	A		14	14
46.8	A		13	13
52.0		B	12	
55.4		B	11	
57.2	A		10	10
58.5		B	9	
64.9		B	8	
68.4	A		7	7
71.3		B	6	
74.2		B	5	
75.6		B	4	
77.1	A		3	3
78.7		B	2	
94.8	A		1	1
				66

mean viewing time for subjects in the move through, dominating, path classification was observed, but a correlation was shown to be not proven.

In Display 8 a correlation between the percentage of unit fixations in near sectors to total unit fixations was not proven.

For Display 11 there were fourteen subjects with a response to linger in the space, and twenty-six subjects with a response to move through the space. The percentages of unit fixations in the near sectors to total unit fixations are given in the Wilcoxon Sum of Ranks test, Table XXXVIII. A correlation between higher percentages for subjects with responses to linger in the space was shown to be probably significant ($z = 2.09$; $P < 5\%$).

A questionaire of the importance of each stereoscopic display relative to the stereoscopic motion picture was given in Table XXIX. Ranks of importance were obtained from the responses of subjects 41 and 42, and these were compared with ranks of the stimulation scores for the twelve displays given in Table XX.

A correlation between the importance given to

Table XXXVIII. Percentage Unit Fixations in Near Sectors. Display 11.

$\frac{N}{T}$ %	Linger	Move through	Rank values i	Rank values ii	A Ranks i	A Ranks ii	B Ranks i	B Ranks ii
0		B	1	40				
1.3		B	2	39				
9.2		B	3	38				
13.8		B	4	37				
13.9		B	5	36				
14.0		B	6	35				
16.7		B	7	34				
16.8	A		8	33		33		
17.0		B	9	32				
19.4		B	10	31				
2o.0	A		11	30		30		
20.4	A		12	29		29		
21.4		B	13	28				
23.4	A		14	27		27		
24.4		B	15	26				
25.7		B	16	25				
26.1		B	17	24				
26.5		B	18	23				
26.6	A		19	22		22		
28.6		B	20	21				
29.0		B	21	20				
29.7		B	22	19				
31.1	A		23	18		18		
31.6	A		24	17		17		
32.1		B	25	16				
32.6		B	26	15				
32.7	A		27	14		14		
33.7		B	28	13				
34.2		B	29	12				
38.6		B	30	11				
39.2		B	31	10				
41.6		B	32	9				
46.0			33	8		8		
46.3		B	34	7				
48.8	A		35	6		6		
52.1		B	36	5				
61.6	A		37	4		4		
68.1	A		38	3		3		
70.5	A		39	2		2		
76.0	A		40	1		1		
						214		

the displays by subject 41 and the ranks of intensity of stimulation was not proven. A correlation between the importance given to the displays by subject 42 and the ranks of intensity of stimulation was shown to be statistically significant ($D^2 + T = 49$; $P < 1\%$). Correlation between ranks of the combined scores of importance and ranks of intensity of stimulation was probably significant ($D^2 + T = 79$; $P < 5\%$).

Similar correlations were suggested in the comparison of ranks of importance with direction of stimulation ranks. Correlation was not proven for subject 41, but a probably significant correlation was suggested for subject 42 ($D^2 + T = 82$; $P < 5\%$). Correlation between ranks of the combined scores of importance and ranks of the direction of stimulation was probably significant ($D^2 + T = 107$; $P < 5\%$).

XVI. RELATIONSHIPS

THAT correlation between the positive intensity scores and positive direction scores of subjects was statistically significant. A display that was found to be interesting or very interesting by a subject tended to be classified as fine or very fine. This was in agreement with the graphical illustration of the total intensity and direction scores of each display.

THAT correlation between the positive intensity scores and creativity scores of subjects was probably significant.

THAT correlation between Factor I and positive intensity scores, and Factor I and positive direction scores, was probably significant. This personality factor in part is a measure of sensitivity and an important factor in the creativity specification.

THAT correlation between Factor E and the frequency of responses of command was probably significant. An assertive individual has tended to provide more frequent responses of command in architectural space.

THAT, for Displays 2, 3, 4, 5, 6, 7, 8, 9 and 11, a correlation between total viewing time and total intensity of stimulation scores was statistically significant. A correlation between total viewing time and total direction of stimulation scores for these displays was also statistically significant.

THAT there was a statistically significant correlation of greater interest shown in Display 1 by subjects whose responses were move through, dominating, path or move through, command, path than by subjects who responded in a different way to the subjective response questionaire.

THAT, in Display 10, it was probably significant that subjects in the move through, dominating, path and move through, command, path classification of subjective responses tended to have higher direction of stimulation scores.

THAT, in Display 6, correlation between lower percentages of fixations in distant sectors for subjects in the move through, command, path classification was probably significant.

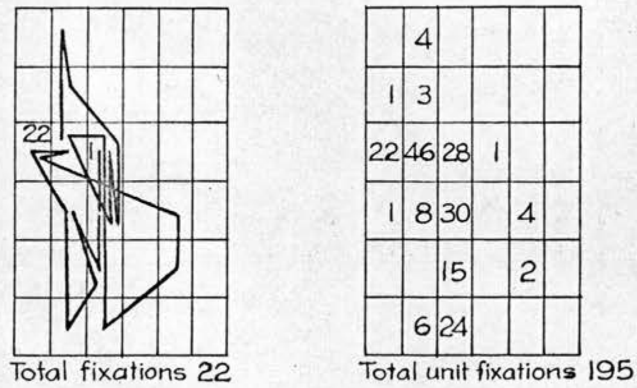
THAT, in Display 11, correlation between higher percentages in near sectors for subjects whose response was to linger in the space was probably significant.

CONCLUSIONS

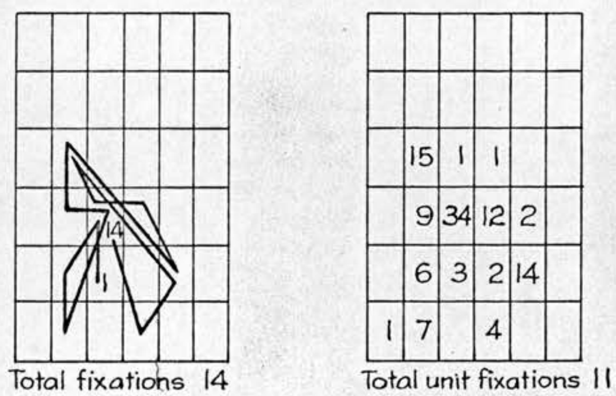
XVII. CONCLUSIONS RELATING TO HYPOTHESES

The subjective responses of groups of subjects will be reviewed and illustrated from recordings of eye fixations.

Fixation sequences and the sector analysis of unit fixations for Displays 1 and 2 are given in Fig. 52-54. In Display 1 a path was acknowledged by twenty-six subjects, Table XVII. The display presented a barrier to thirteen subjects. The sectors which represented the space between the shell vaults in Display 1 are seen to represent steelwork beneath the shell vault in Display 2, Fig. 40. The eye fixation recordings of subject 39, Fig. 52 and 53, illustrate visual interest on a path through space in Display 1 and on a barrier in Display 2. The subjective responses were move through, dominating, path for Display 1 and linger, command, barrier for Display 2. An increasing emphasis on the shell vault in Display 2 is shown in the recording of fixations of subjects 27 and 28, Fig. 54. The subjective responses were move through, inappropriate,

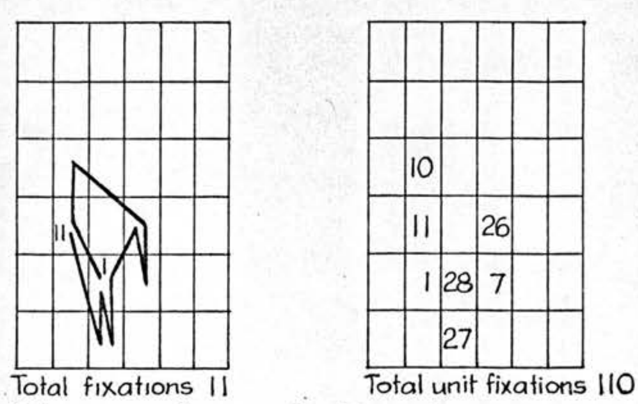


Subject 35. Linger, Command, Path.



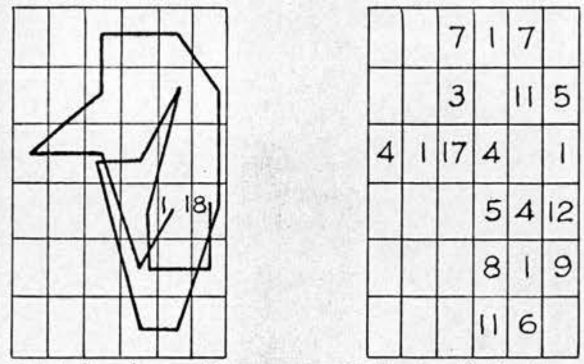
Subject 39. Move through, Dominating, Path.

Fig. 52. Analysis of Eye Fixations.
Display 1.

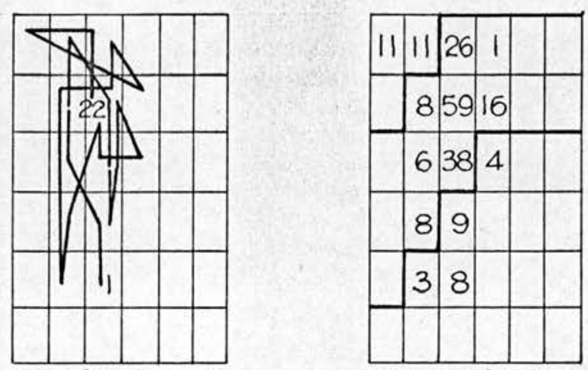


Subject 39. Linger, Command, Barrier.

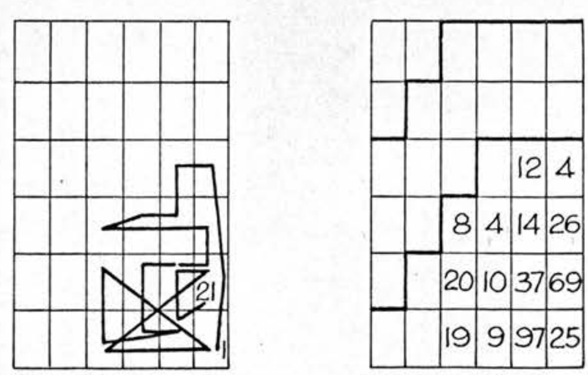
Fig. 53. Analysis of Eye Fixations.
Display 2.
Subject 39.



Subject 27. Move through, Inapprop., Path.



Subject 28. Move through, Command, Path.



Subject 36. Inapprop., Inapprop., Barrier.

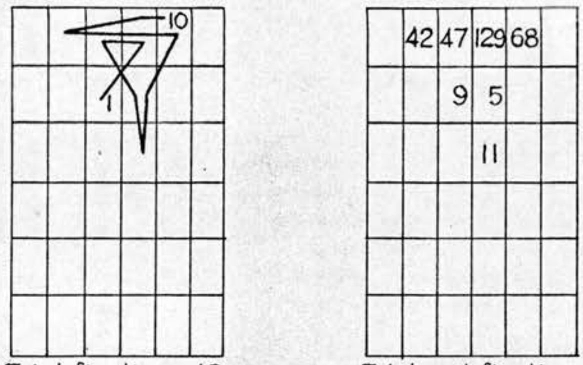
Fig. 54. Analysis of Eye Fixations.
Display 2.

path for subject 27, and move through, command, path for subject 28. A diagrammatic illustration of the shell vault as a threshold indicates not only a high percentage of unit fixations in these sectors, but also the repeated crossing of these sectors in the fixation sequence diagram. A response of inappropriate, inappropriate, barrier is illustrated in the eye fixations of subject 36.

The subjective responses to Display 2, Table XVIII, indicate that the maximum number of subjects in any combination of responses was six. There were, however, twenty-five subjects who responded to the classification of barrier, Table XVII.

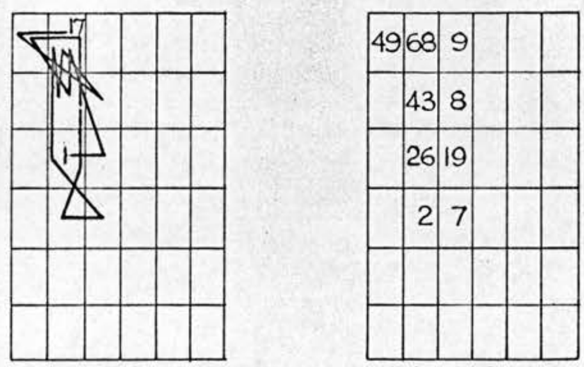
For Display 3 there were twenty-four subjects whose response was to linger in the space. Eleven subjects accepted the classification to move through the space. In Display 4 a reversal is shown with twenty-four subjects whose response was to move through the space. There was little evidence of the spiral stair in Display 3. The analysis of eye fixations has shown the importance given to this in Display 4, Table XXIII. The changes in subjective responses are attributed to the perception of the stair as a path through space. An increase in the direction of stimulation score for Display 4 was illustrated in Table XX. The eye fixations to Display 3 emphasized the visual importance of the platform overhead. This was particularly seen in the analysis of fixations for subjects whose responses were in the classification of dominating. Illustration of this is given in Fig. 55 for subjects 28 and 35. The fixation sequences of these subjects may be contrasted with those of subject 8 whose response was linger, command and path.

The eye fixation sequences and sector analysis of unit fixations for Display 4 are illustrated in Fig. 56. The percentage of unit fixations in the stair sectors to the total unit fixations was given for all subjects in Table XXIII. The visual importance of the stair to subjects in the move through, command, path classification is illustrated from the fixations of subjects 15 and 34. The total unit fixations were 84 and 720 respectively. It is seen that the first twenty fixations of subject 34 occurred within the stair sectors. On the other hand, the sequence of fixations for subject 13 indicates initial viewing of the shell vault in the display prior to repeated fixations in the stair sectors. The subjective responses of subject 9 were linger, command, barrier and the sequence of fixations diagram clearly illustrates a disregard of the stair. This is



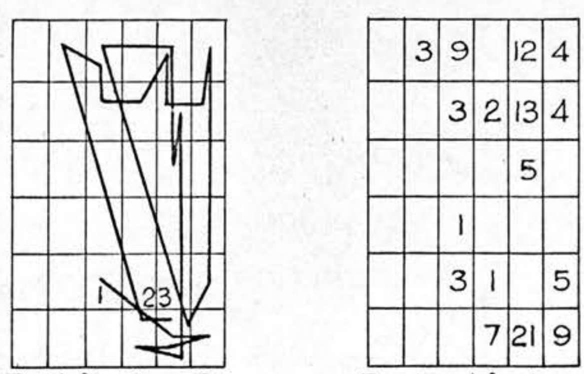
Total fixations 10 Total unit fixations 311

Subject 35. Move through, Dominating, Barrier.



First 17 fixations Total unit fixations 231
Total fixations 25

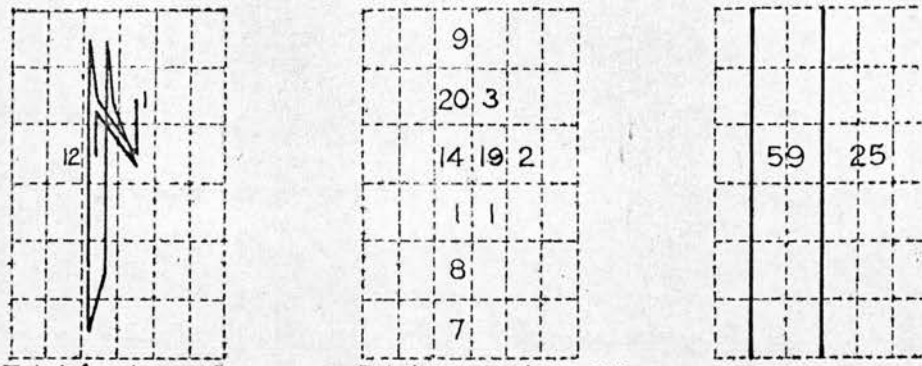
Subject 28. Linger, Dominating, Barrier.



Total fixations 23 Total unit fixations 102

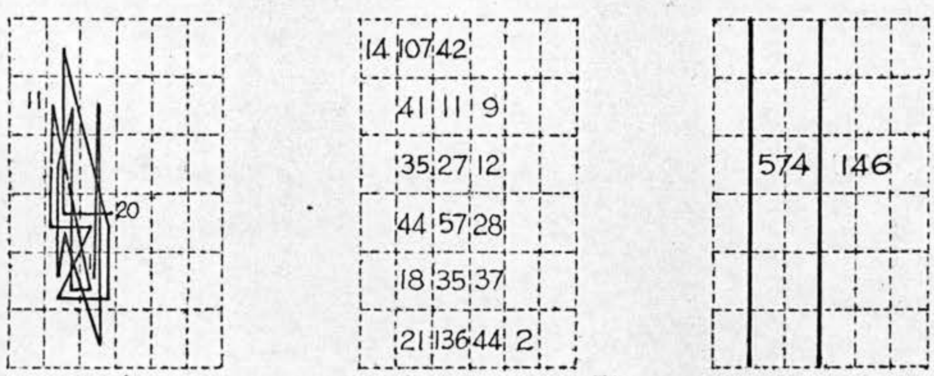
Subject 8. Linger, Command, Path.

Fig. 55. Analysis of Eye Fixations.
Display 3.



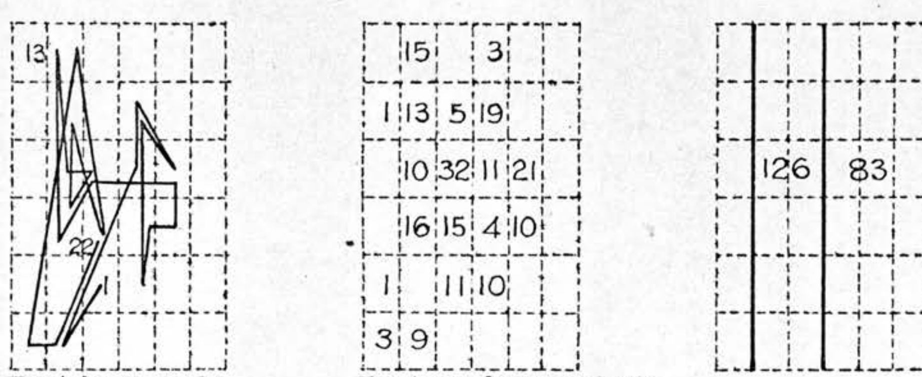
Total fixations 12 Total unit fixations 84

15. Move through, Command, Path. $\frac{S}{T} = 70.2$



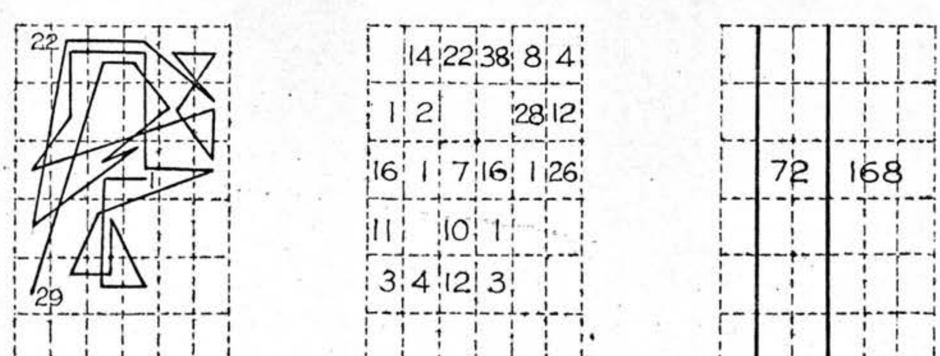
First 20 fixations
Total fixations 39 Total unit fixations 720

34. Move through, Command, Path. $\frac{S}{T} = 79.7$



Total fixations 22 Total unit fixations 209

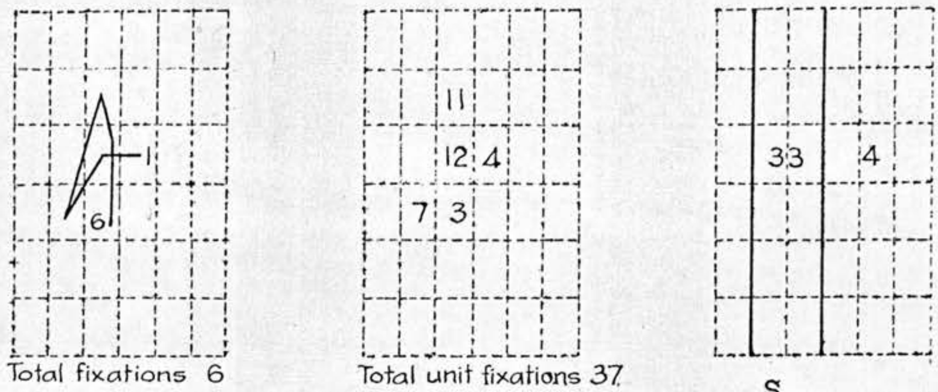
13. Move through, Dominating, Path. $\frac{S}{T} = 60.3$



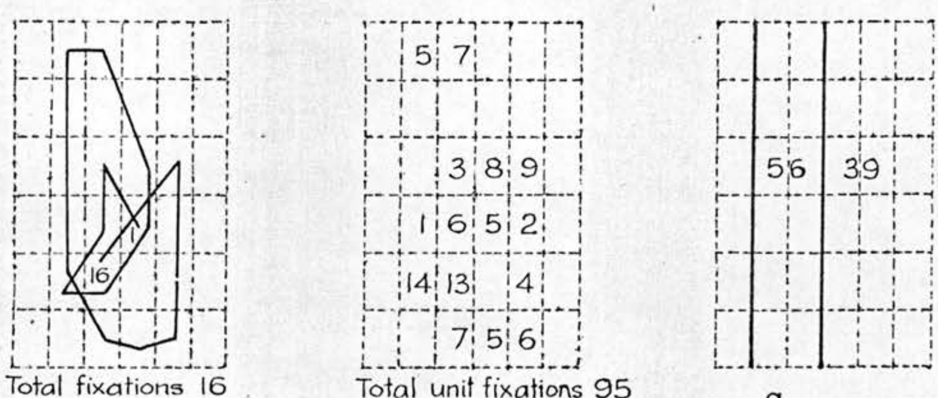
Total fixations 29 Total unit fixations 240

9. Linger, Command, Barrier. $\frac{S}{T} = 30.0$

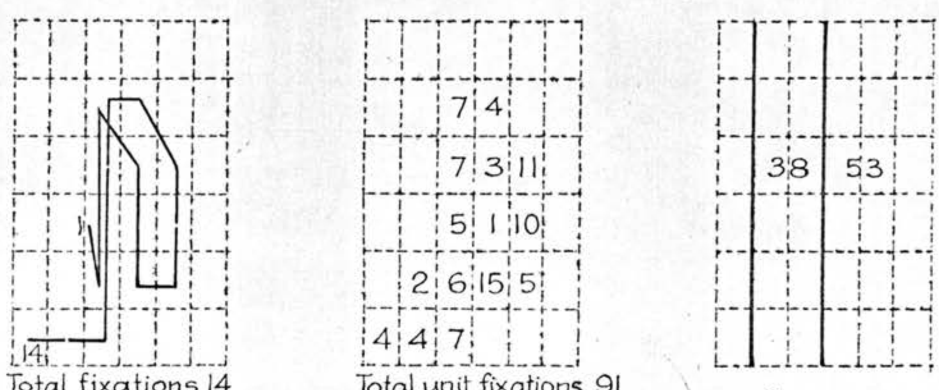
Fig. 56. Analysis of Eye Fixations.
Display 4.



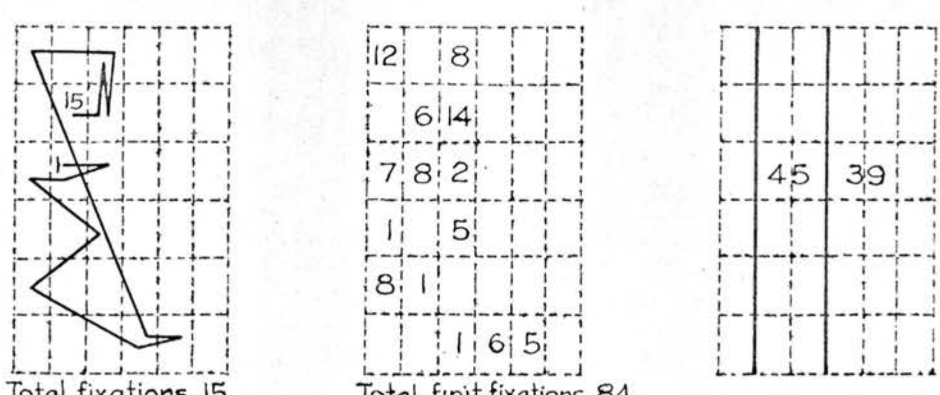
40. Linger, Command, Path. $\frac{S}{T}$ = 89.2



4. Linger, Command, Path. $\frac{S}{T}$ = 58.9



39. Linger, Dominating, Path. $\frac{S}{T}$ = 41.8



20. Move through, Inapprop., Path. $\frac{S}{T}$ = 53.6

Fig. 56. Continued.
Display 4.

also shown in the sector analysis of unit fixations. The eye fixations of a further four subjects are illustrated in Fig. 56.

Table XVIII has indicated that there was little agreement in subjective responses for Display 5. The largest group with a similar combination of subjective responses was eight subjects in the classification of linger, dominating, inappropriate. Illustration of the eye fixations of two subjects in this group is given in Fig. 57. The analysis of subject 31 indicates that in this instance the temporary structure of the workmens' platforms was given attention. The overhead steelwork of the proscenium arch was emphasized in the recording of subject 8.

In the eye fixation analysis of subjects 9 and 16 there is little evidence of interest in any particular part of the display. The fixation sequences of these subjects would seem to illustrate an effective search scan for acquiring information from the display. In several other displays an initial visual interest in one element has led to only peripheral viewing of other sectors. This was shown to be the general case in Display 4.

Total fixations 14

	15	6			
	7	6	4		
1		2			
1	6	3			
14	22				

Total unit fixations 87

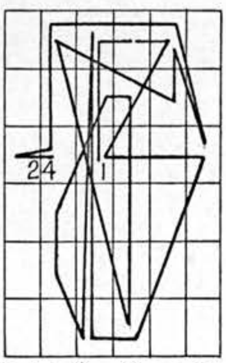
Subject 31. Linger, Dominating, Inapprop.

Total fixations 12

		7	5	10	14
			11	8	6
			7	7	
				8	
			2		
			10		

Total unit fixations 95

Subject 8. Linger, Dominating, Inapprop.

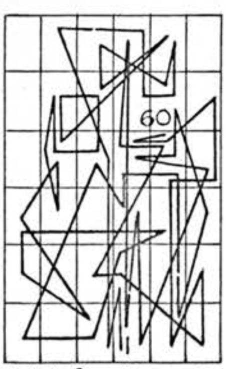


Total fixations 24

	26	19	7	11	
		3	19	9	
4	5	24	1	1	14
	3				
	3	1	1		
		29	18	1	

Total unit fixations 199

Subject 9. Linger, Dominating, Barrier.



Total fixations 60

	5	12	17	15	
	19	42	36	37	2
1	76	13	52	67	12
20	27	2	14	26	5
14		8	23	9	4
10	1	21	20	29	8

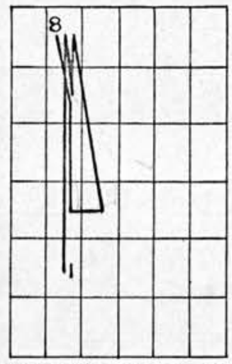
Total unit fixations 647

Subject 16. Move through, Inapprop., Path.

Fig. 57. Analysis of Eye Fixations.
Display 5.

For Display 6, twenty-two subjects responded to the classification of move through, command, path. A lower percentage of unit fixations in distant sectors for this group has been shown to be probably significant. It is suggested that these subjects, because of the greater interest shown in the stair sectors, were generally in command of the stair as a path through space. On the other hand, subjects who responded to the classification of move through, dominating, path tended to be dominated by the distant sectors and the anticipation of crossing a threshold at the top of the stairs. An illustration of the eye fixations of four subjects whose responses were move through, command, path is given in Fig. 58. Analysis of the fixations of two further subjects in this classification of subjective responses was included in Fig. 47. An illustration of the eye fixations of subjects whose responses were move through, dominating, path was given in Fig. 47 for subjects 19 and 25.

From the recordings of eye fixations it is suggested that subjects with responses of move through, command, path or move through, dominating, path derived meaning from Display 6. The fixation sequence of subject 40, with responses of linger, command and path, also suggests that there was meaning for this

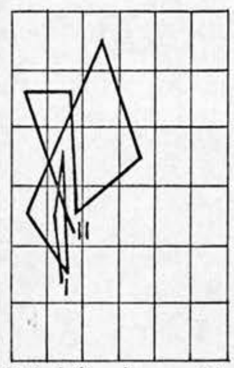


Total fixations 8

	30	1			
	8				
	1	1			
	8	3			
	4				

Total unit fixations 56

Subject 15. Move through, Command, Path.

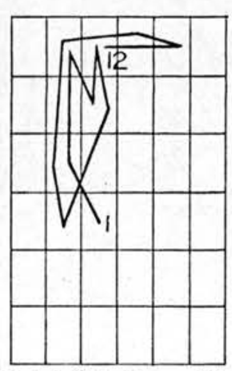


Total fixations 11

	1	9			
3	9		1		
	7	1	3		
5	12	1			
	12	1			

Total unit fixations 65

Subject 7. Move through, Command, Path.

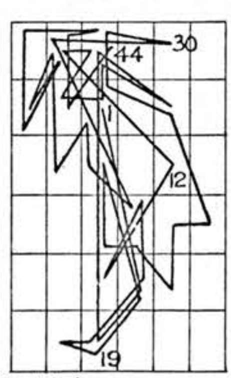


Total fixations 12

	9	30	28	10	
	1	10			
	10	1			
	4	5			

Total unit fixations 108

Subject 4. Move through, Command, Path.



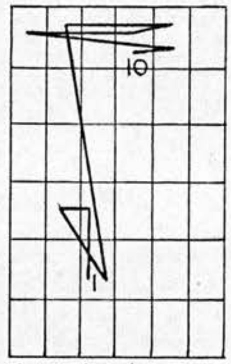
Total fixations 44

5	76	48	2	12	
16	19	30	2	17	
	11	26	4	9	
		15	32	10	9
		29	37	10	
	11	19	8		

Total unit fixations 457

Subject 5. Move through, Command, Path.

Fig. 58. Analysis of Eye Fixations. Display 6.

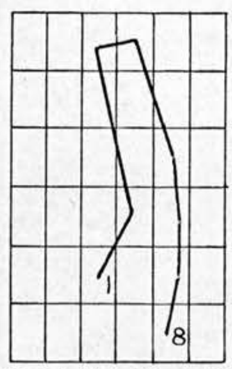


Total fixations 10

8	22		11	13	
	5	2			
		9			

Total unit fixations 70

Subject 25. Move through, Dominating, Path.

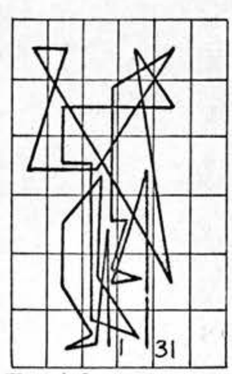


Total fixations 8

		3	3		
			1		
			2	3	
			6	8	
		4	2	3	
			1	2	

Total unit fixations 38

Subject 40. Linger, Command, Path.



Total fixations 31

7	14	2	16	15	
1	6	10	2	14	
6	2	34	21		
	17	18	13	1	
	6	27	12	6	
	7	25	21		

Total unit fixations 303

Subject 21. Inapprop., Inapprop., Path.

Total fixations 43

147	214	177	44	29	4
31	27	10	5	2	
18	6	11	1	2	
4	7	4	5	6	4
2		1	3	2	4
		2	1		6

Total unit fixations 779

Subject 17. Linger, Dominating, Barrier.

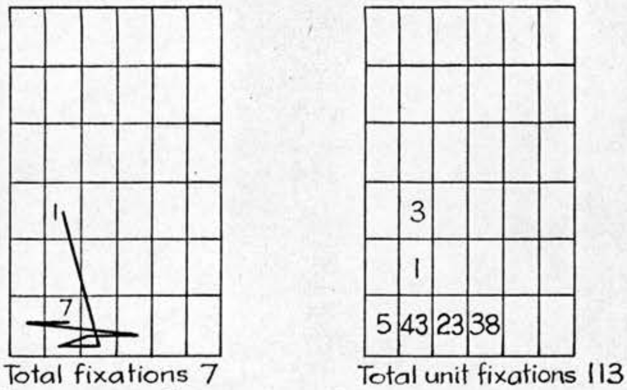
Fig. 59. Analysis of Eye Fixations.
Display 6.

subject, Fig. 59. But there is a lack of subjective meaning evident in the fixation sequence of subject 21. The subjective responses were inappropriate, inappropriate, path.

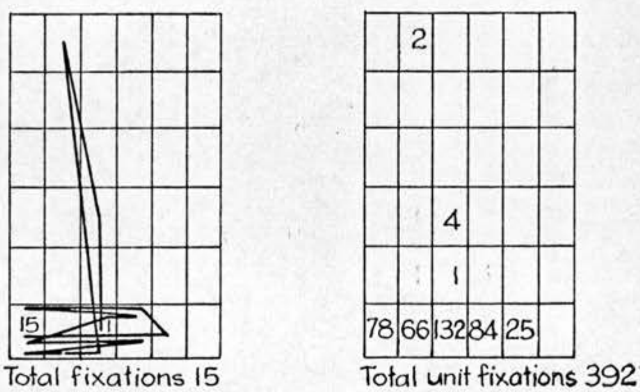
The maximum viewing time for Display 6 was that of subject 17. The fixation sequence reveals a continual crossing from stair to distant sectors, Fig. 59. This may be contrasted with the fixation sequence of subject 40 whose viewing time was the shortest of the group of forty subjects.

In Display 7, fourteen subjects responded to the classification of linger, command, barrier. The eye fixations of four subjects in this group are illustrated in Fig. 60. The harbour is seen to be the centre of interest of subjects 3, 31 and 35. In the analysis of subject 32 interest extended to the tall buildings across the harbour. There were eight subjects in the subjective response classification of linger, command, inappropriate. The fixation analysis of these subjects indicates an increased interest in the distant buildings. This is most clearly demonstrated in the horizontal eye movements to the final fifteen fixations of subject 10, Fig. 60.

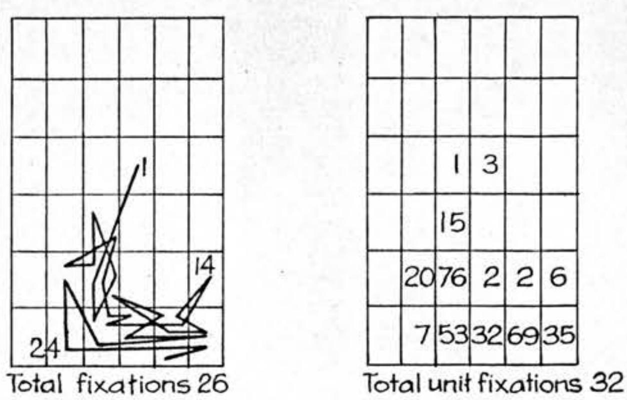
For Display 8, nineteen subjects responded to



Subject 31. Linger, Command, Barrier.

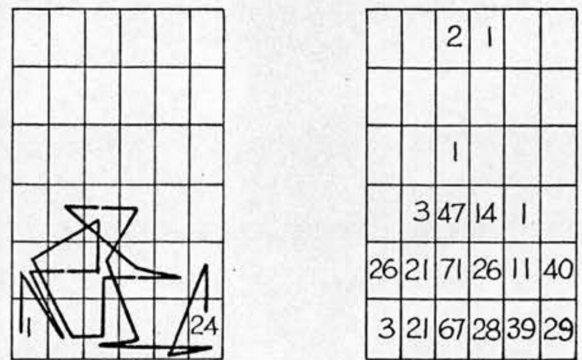


Subject 35. Linger, Command, Barrier.



Subject 3. Linger, Command, Barrier.

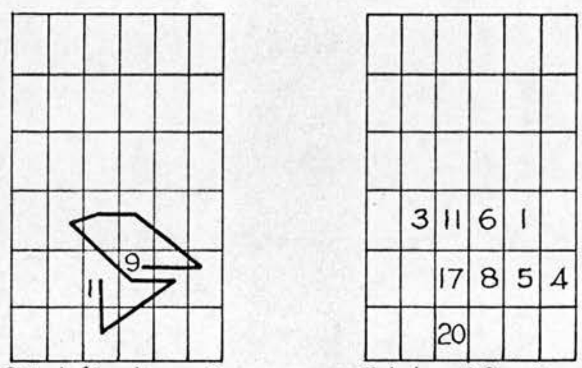
Fig. 60. Analysis of Eye Fixations.
Display 7.



First 24 fixations
Total fixations 36

Total unit fixations 451

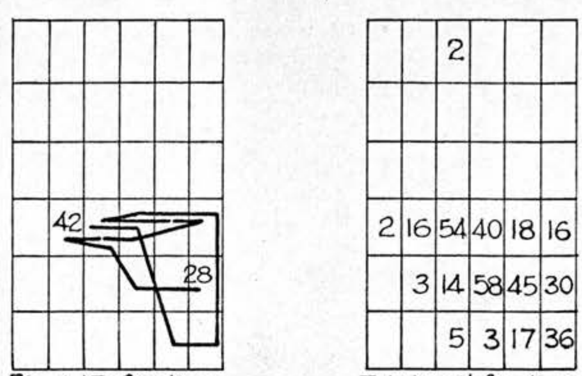
Subject 32. **Linger, Command, Barrier.**



Total fixations 9

Total unit fixations 75

Subject 37. **Linger, Command, Inapprop.**



Final 15 fixations
Total fixations 42

Total unit fixations 359

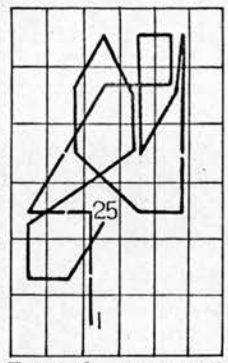
Subject 10. **Linger, Command, Inapprop.**

Fig. 60. Continued. Display 7.

the classification of move through, command, path. In general the fixations sequences of these subjects indicated an initial acknowledgment of the path in the display. This is illustrated from the analysis of subject 25 in Fig. 61, and subjects 9 and 18 in Fig. 48.

Seven subjects responded to the classification of move through, dominating, path. In the fixation sequence of subject 35, Fig. 62, fixations 3 to 8 are shown to occur on the ramp. An initial blink is noted in the eye fixation recordings of this subject and this is shown additionally in the analysis of Displays 7 and 9, Fig. 60, 63. The subject's interest moved from the ramp to distant sectors for fixations 9 to 18, and then to details in the near sectors, fixations 19 to 21. Final fixations 22 to 25 are shown to occur on the ramp.

A similar sequence is shown in the analysis of eye fixations of subject 37, Fig. 62. The subjective response classification of this subject was move through, command, path. The analysis of this subject may be contrasted with that of subject 7, Fig. 62. The subjective response classification was inappropriate, inappropriate, path. A diagrammatic representation of the ramp is given in the figure.

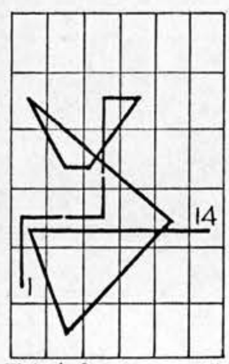


Total fixations 25

		6	3	14	
	7	9	7	11	
	16	1	19	14	
14	3	7	9	9	
7	7	5			
		8			

Total unit fixations 176

Subject 25. **Move through, Command, Path.**

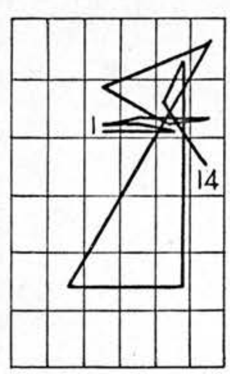


Total fixations 14

5	1	7	4		
	7	10			
33	4	2		8	5
6	1				
	6				

Total unit fixations 99

Subject 15. **Move through, Command, Path.**



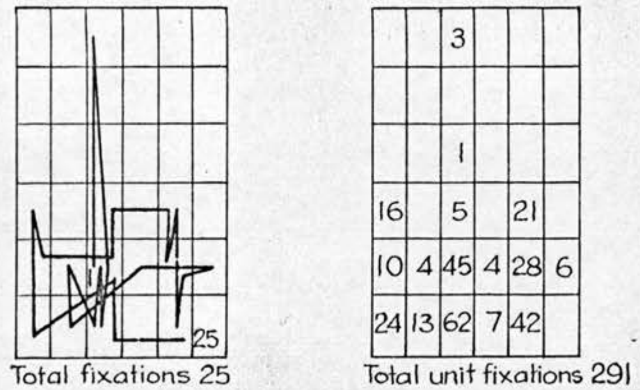
Total fixations 14

				7	4
		18	20	24	10
				1	7
1	8			6	

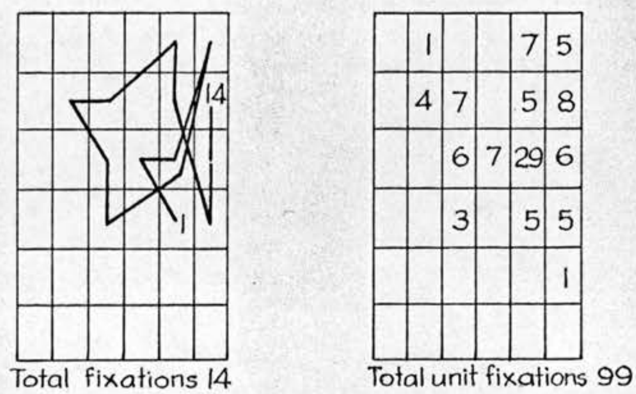
Total unit fixations 106

Subject 26. **Move through, Command, Path.**

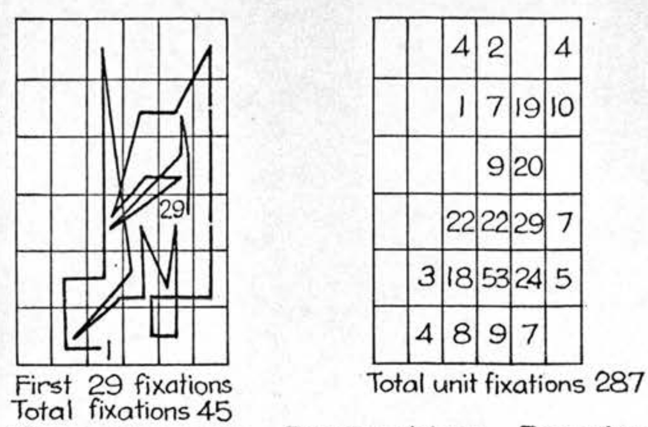
Fig. 61. Analysis of Eye Fixations.
Subjects with Responses of
Move through, Command, Path.
Display 8.



Subject 35. **Move through, Dominating, Path.**

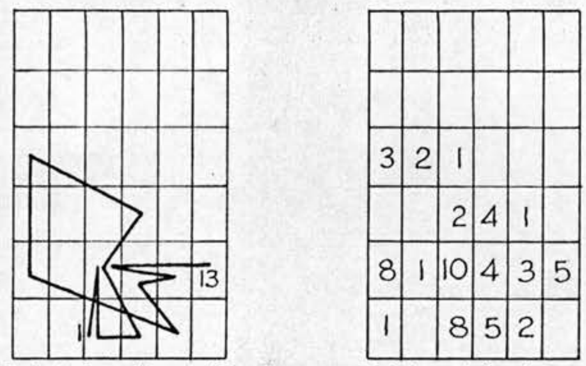


Subject 8. **Move through, Dominating, Barrier.**



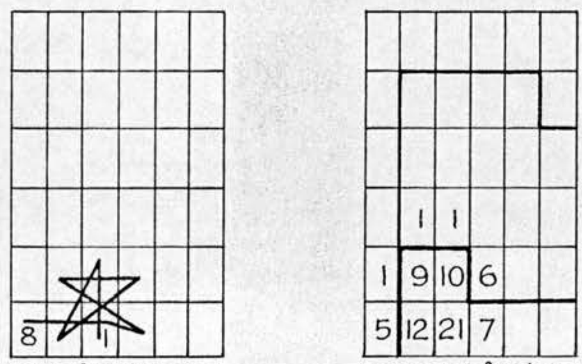
Subject 32. **Move through, Dominating, Barrier.**

Fig. 62. Analysis of Eye Fixations.
Display 8.



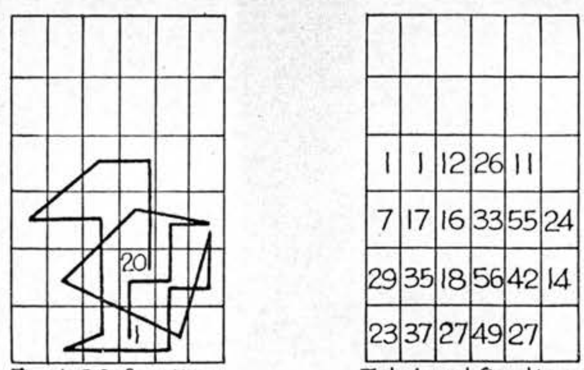
Total fixations 13 Total unit fixations 60

Subject 37. **Move through, Command, Path.**



Total fixations 8 Total unit fixations 73

Subject 7. **Inapprop., Inapprop., Path.**



First 20 fixations
Total fixations 51
Total unit fixations 560

Subject 16. **Move through, Inapprop., Path.**

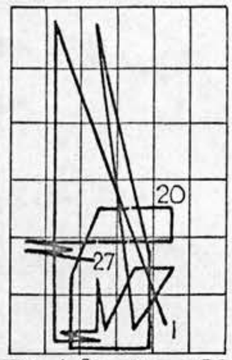
Fig. 62. Continued. Display 8.

The fixation sequence of subject 16 indicates an alternated series of eye fixations on the ramp and distant objects. The first twenty fixations are illustrated in Fig. 62. The subjective response classification of this subject was move through, inappropriate, path.

In Display 9 there were ten subjects in the subjective response classification of linger, dominating, barrier. There were seven subjects in the classification of move through, dominating, path. It is seen from Table XVII that Display 9 was accepted as dominating by thirty subjects, a response largely dependent on the representation of the shell vaults above the position of the subject. The analysis of eye fixations of twelve subjects, Fig. 63, illustrates that fixations were not limited to particular parts of this display. It is noted from Table XX that the display provided high scores of intensity and direction of stimulation.

Eye fixations to Display 10 are illustrated in Fig. 64.

In a relationship between total viewing time and stimulation scores it was found that Displays 1 and 10 were dissimilar to the remaining displays.

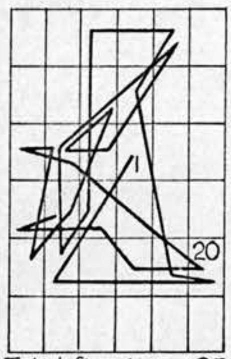


Total fixations 27

	2	2			
	1	1			
	1	5	8	2	
9	22	39	20	13	
2	41	10	35		

Total unit fixations 213

Subject 35. Linger, Dominating, Barrier.

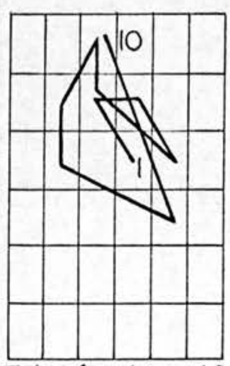


Total fixations 25

		8	1	12	
	2	16	6		
11	42	13	8	1	
8	11	12			
4	20	1	2	7	9

Total unit fixations 194

Subject 9. Linger, Dominating, Barrier.

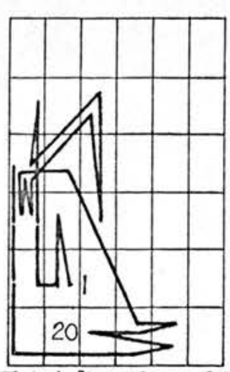


Total fixations 10

		37	1		
	8	9	3		
	6		5	11	
	1	1		8	

Total unit fixations 90

Subject 4. Move through, Dominating, Path.



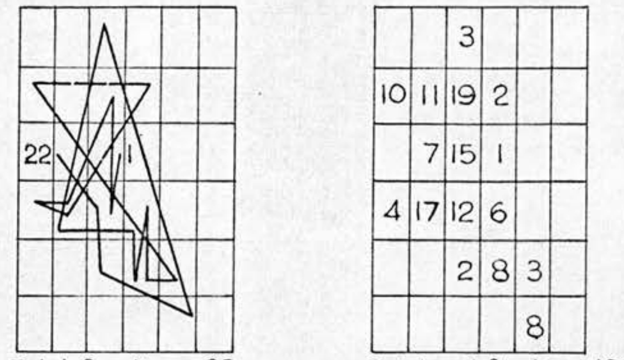
Total fixations 26

1					
6		28			
44	11	1			
96	5	5	1		
49	18				
18		9	38	18	

Total unit fixations 348

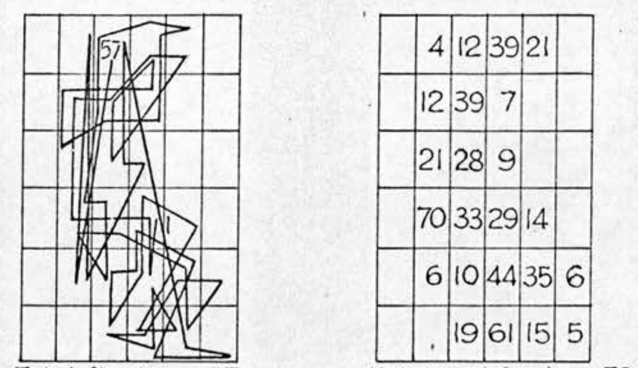
Subject 33. Move through, Dominating, Path.

Fig. 63. Analysis of Eye Fixations.
Display 9.



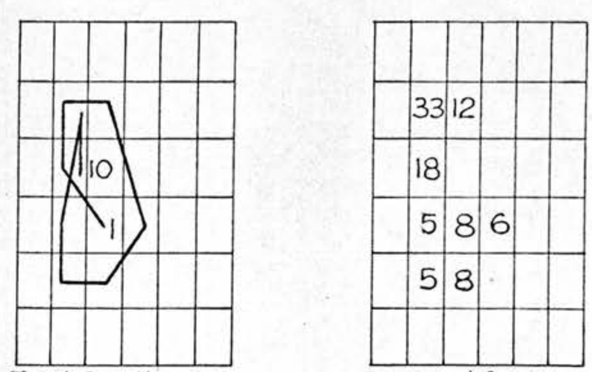
Total fixations 22 Total unit fixations 128

Subject 20. Linger, Dominating, Inapprop.



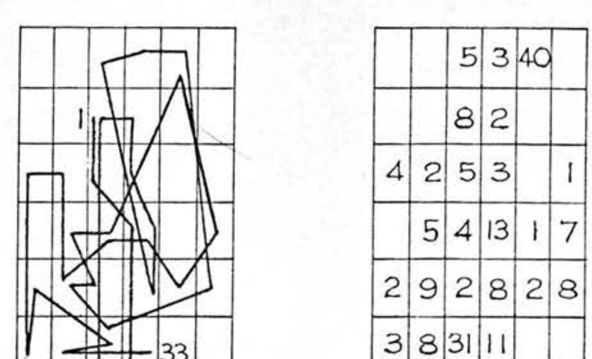
Total fixations 57 Total unit fixations 539

Subject 10. Move through, Dominating, Inapprop.



Total fixations 10 Total unit fixations 95

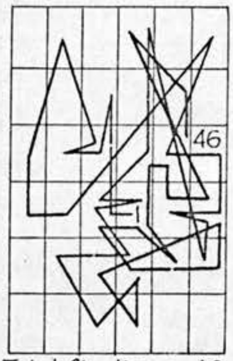
Subject 18. Inapprop., Dominating, Inapprop.



Total fixations 33 Total unit fixations 187

Subject 8. Inapprop., Dominating, Inapprop.

Fig. 63. Continued. Display 9.

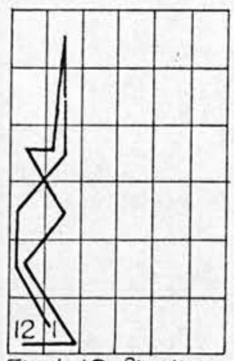


Total fixations 46

	2		5	1	4
	1	6	4	6	
2	6	29	17	18	2
2	6	23	36	20	23
	4	22	19	7	11
		5	6		

Total unit fixations 287

Subject 36. Inapprop., Dominating, Barrier.

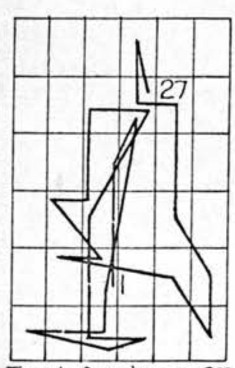


First 12 fixations
Total fixations 74

8	8	13	13	2	
10	15	31	34	1	
5	59	35	14	9	
32	69	32	24	18	
37	44	9	30	38	17
124	71	47	31	22	36

Total unit fixations 938

Subject 34. Move through, Command, Path.

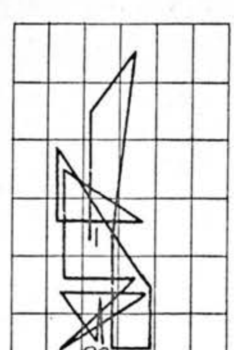


Total fixations 27

		1	9		
		16	27	5	
		15		1	
	5	15		8	
	3	27		7	9
11	12	17	14		12

Total unit fixations 214

Subject 31. Linger, Inapprop., Inapprop.



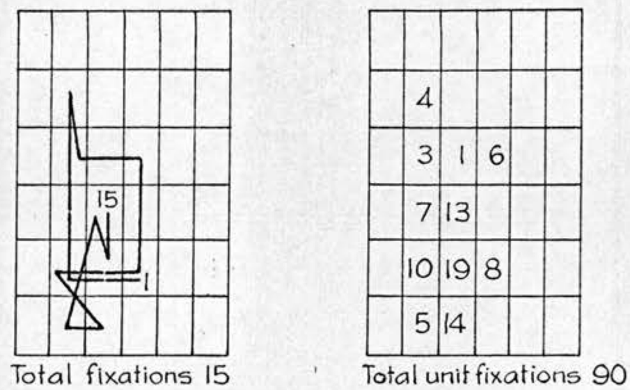
Total fixations 22

			2		
	1	6			
	4	7			
	16	18	7		
	12	32	26	1	
	15	81	17		

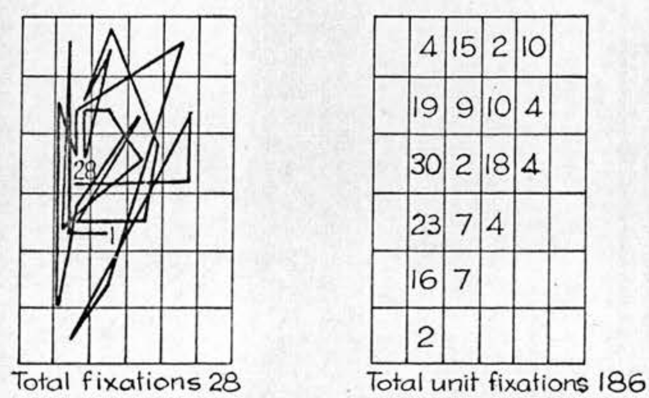
Total unit fixations 245

Subject 13. Inapprop., Inapprop., Inapprop.

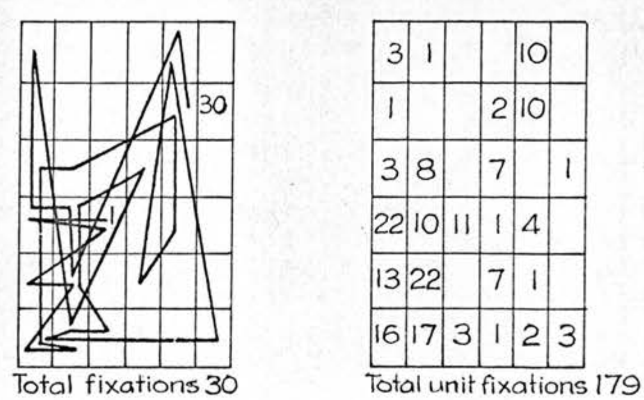
Fig. 63. Continued. Display 9.



Subject 27. Move through, Inapprop., Path.



Subject 39. Move through, Inapprop., Path.



Subject 9. Move through, Command, Path.

Fig. 64. Analysis of Eye Fixations.
Display 10.

There was statistical significance of greater interest in Display 1 by subjects whose response was move through, dominating, path or move through, command, path than by subjects who responded in a different way. In Display 10 a difference in aesthetic evaluation was probably significant for subjects in the above subjective response classification.

Displays 1 and 10 record the same architectural space but it is viewed from different positions. In Display 1 the subject viewed the space between the two groups of shell vaults, and a distant view of the harbour was screened by stairs and temporary structures. In Display 10 the subject viewed the space from a temporary ramp which connected the groups of shell vaults. From the probable correlations it is suggested that a subject whose responses were move through and path for Display 1 found the space interesting for there was seen to be provision for movement and anticipation of a less restricted view. Later, in Display 10, the location of the building had been established and there was then greater emphasis on aesthetic evaluation by subjects in the above classification of subjective responses. The total stimulation scores of the forty subjects were similar in the two displays. From

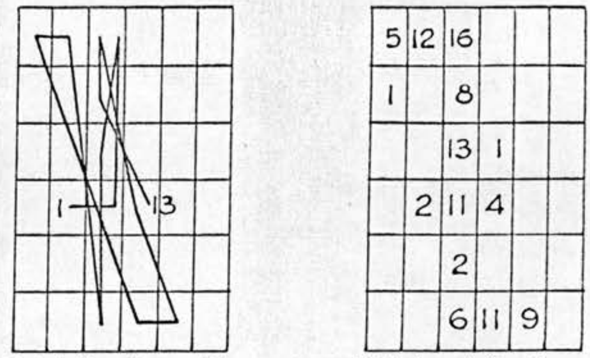
Table XX the intensity and direction scores for Display 1 were 37 and 15 respectively. The corresponding scores for Display 10 were 38 and 14. In general, the higher stimulation scores for subjects whose responses were move through and path suggest that these subjective responses are an evidence that the display had meaning to these subjects.

In Display 11, twenty-six subjects recorded a response to move through the space, fourteen subjects recorded a response to linger. It has been shown that subjects whose response was to linger in the space have tended to provide higher percentages of unit fixations in near sectors. This is illustrated in the analysis of eye fixations of subjects 3 and 16, Fig. 49. Subjects whose response was to move through the space tended to show greater interest in evidences of a path through space and in distant sectors of the display. The fixation analysis of subjects 27 and 30 was given in Fig. 49.

In this display the representation of a scaffold handrail led from either side of the subject's apparent location on a ramp. The provision of a path was acknowledged by thirty-three subjects.

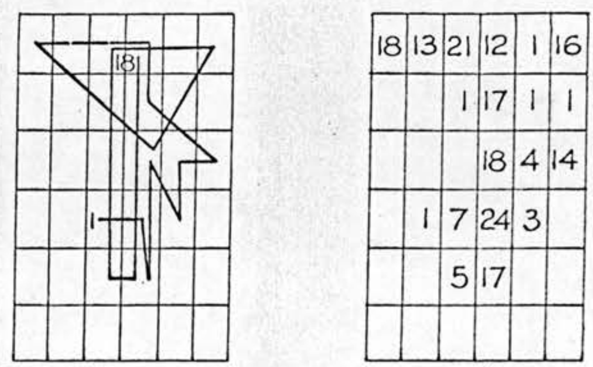
The fixation sequences of subjects whose response was to move through the space tended to emphasize the threshold of the overhead shell vault by repeated eye movements between near and distant sectors. There is a high percentage of these eye movements in the fixation sequence of subject 4, Fig. 65. This may be contrasted with the analysis of subject 3.

In Display 12 there were eleven subjects whose subjective responses were in the linger, dominating, barrier classification. There were seven subjects in the inappropriate, dominating, barrier classification. The recordings of eye fixations of these subjects have emphasized the visual importance of the scaffold and reinforcing steel. There were nine subjects who acknowledged a path in this display. The eye fixation recordings of subjects 4, 11 and 28 are illustrated in Fig. 66, 67. A great deal of interest was shown in the workmens' ladder by subject 11. This is illustrated in the fixation sequence diagram by repeated vertical eye movements along the ladder, and also in the sector analysis of unit fixations. The ladder is represented by six sectors or 16.7 percent of the display. For subject 11, 56 percent of the total unit fixations occurred in these sectors. The subjective responses were move through, dominating, path.



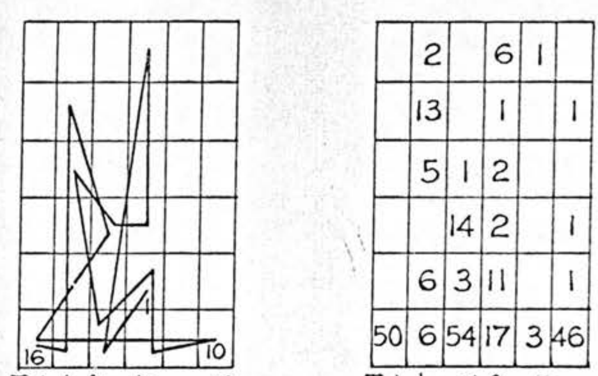
Total fixations 13 Total unit fixations 101

Subject 4. Move through, Command, Path.



Total fixations 18 Total unit fixations 194

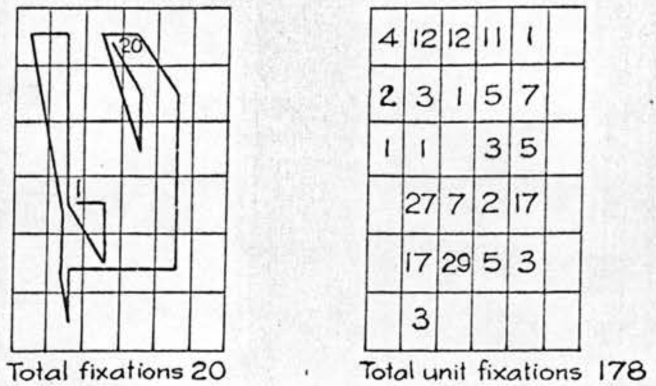
Subject 2. Move through, Command, Path.



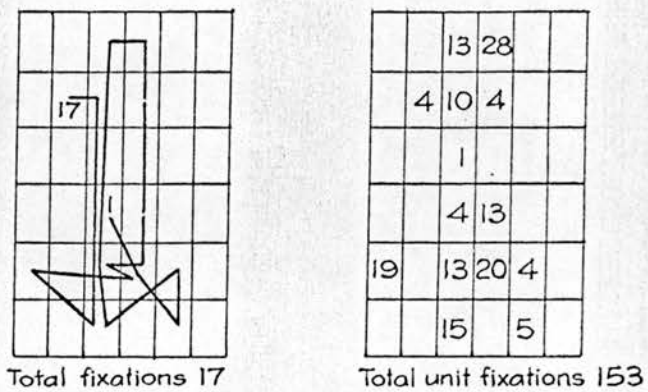
Total fixations 16 Total unit fixations 246

Subject 6. Linger, Command, Path.

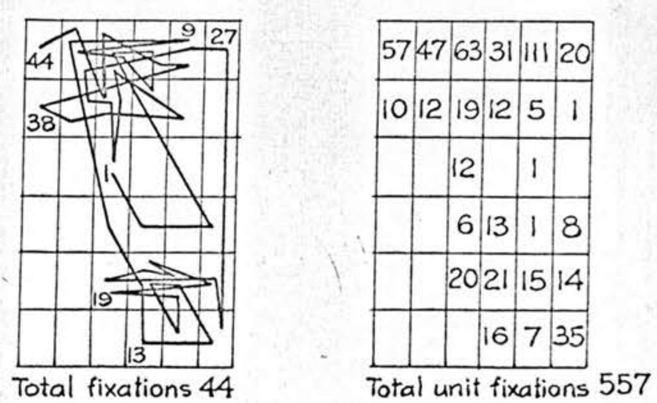
Fig. 65. Analysis of Eye Fixations.
Display 11.



Subject 22. Move through, Dominating, Path.

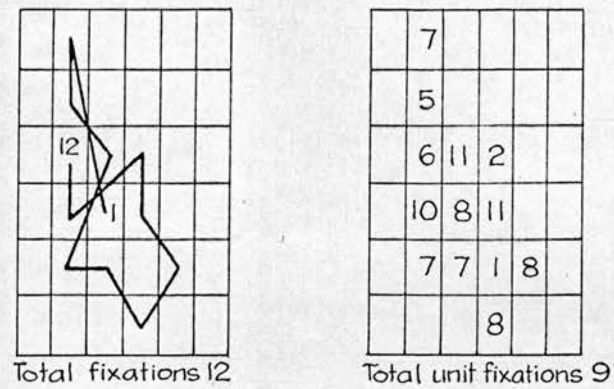


Subject 15. Move through, Dominating, Path.

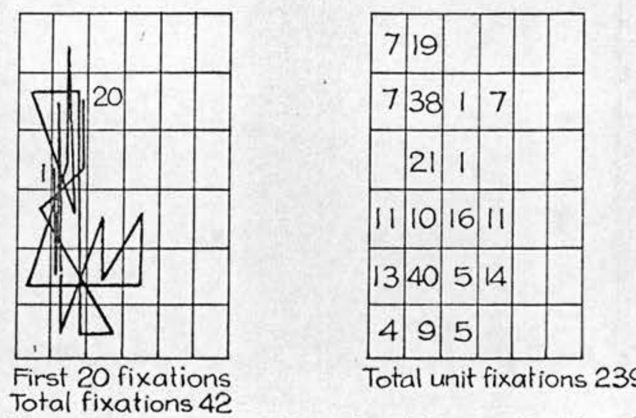


Subject 3. Linger, Dominating, Path.

Fig. 65. Continued. Display 11.

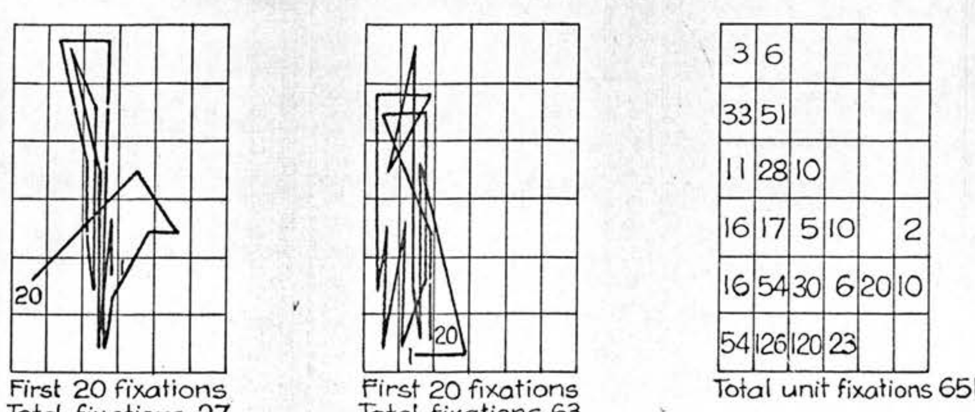


Subject 4. Move through, Command, Path.



Subject 11. Move through, Dominating, Path.

Fig. 66. Analysis of Eye Fixations.
Display 12.



Move through, Dominating, Path.

Display 4. Display 12.

Fig. 67. Comparison of Eye Fixation Sequences.
Subject 28.

A similar emphasis on the workmens' ladder is shown in the eye fixation analysis of subject 28, Fig. 67, and this may be compared with the recording of this subject's fixations in the stair sectors of Display 4 also given in Fig. 67. The subjective responses of subject 28 were move through, dominating, path in Display 12 and move through, command, path in Display 4.

The study of the fixation sequences of individual subjects has shown that there was greater frequency of eye movements which crossed from near to distant sectors in Displays 2, 6 and 11. These displays were recorded on the site of the Sydney Opera House as displays of threshold, Table VIII. From the classification of subjective responses, Table XVII, Displays 6 and 11 have tended to be described as displays of movement.

The recording of initial eye fixations has illustrated the acquisition of information from the displays. This has then led to subjective responses and finally evaluation. It has been suggested from the analysis of eye fixations that, in general, there has been a more effective visual search scan for displays that have provided little agreement in subjective responses. This was illustrated in

Displays 5 and 9. In other displays, particularly 4, 6, 7, 8 and 11, the acquisition of information led to an early acknowledgment of a path or barrier and this then restricted visual search in the display. The eye fixation sequence tended to be less distributed throughout the sectors of the display for a subject who had derived meaning at an early point in the viewing time.

It has been suggested from statistical analyses that a classification of the personality of a subject was related to his subjective response and stimulation. A correlation between high scores of the personality Factor E and subjective responses of command was shown to be probably significant. This has suggested that an assertive individual not only tends to be in command of social relationships but also of his environment. The importance of Factor I in positive stimulation responses has been shown to be probably significant. A high score of this factor suggests greater sensitivity and this is reflected in the creativity specification.

A photometric analysis of Displays 4, 6, 7, 8, 9 and 11 has been carried out and compared with the analysis of eye fixations to these displays. From the projection of stereoscopic displays of spatial sequences, relationships between eye fixations and subjective responses have been suggested that are not dependent on photometric variation within the displays.

It has been shown that in Displays 4, 6, 7, 8 and 11 the analysis of eye fixations of groups of subjects has illustrated the subjective responses of these groups. For individual subjects, the same analysis of eye fixation sequences and unit fixations has given some insight into the perceptive processes.

XVIII. GENERAL CONCLUSIONS

In the selection of spatial sequences for this study importance was given to an understanding of the architect's design intentions, Chapters IV and VIII. The displays of the Sydney Opera House have revealed an incomplete structure, and the contrast of some completed spaces with substantial environmental noise of scaffold and workmens' ramps has been an important part of the study. In many cases the provision of a temporary path through space has been accepted by a group of subjects, and its importance has been illustrated from eye fixations to the displays.

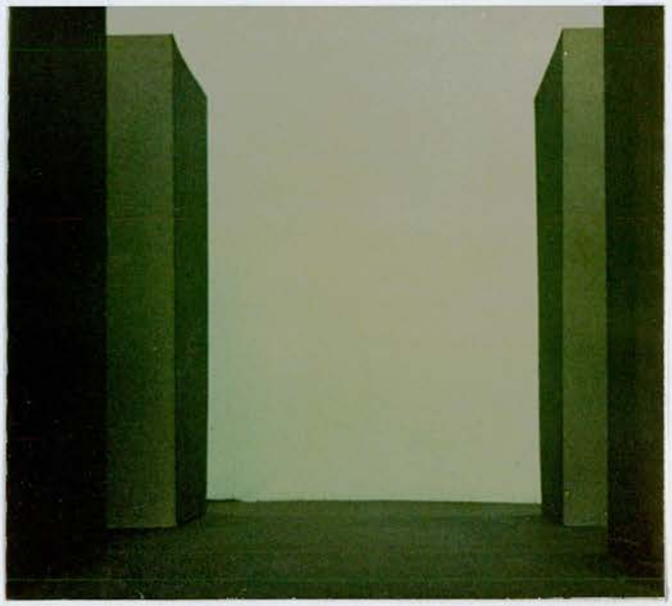
In Displays 3, 4, 6, 7, 8, 9, 11 and 12 a conflict has not generally arisen between the designer's intentions of subjective experience and the responses of the subjects. But in Displays 1, 2, 5 and 10 the architect's design for the completed building and the recording of space in the incomplete building are at variance.

The space between the shell vaults in Displays 1 and 10 was designed for movement to the auditoria. However, at the time of photography at the Sydney Opera House site, movement in this space was restricted by recent concrete work and by an incomplete provision of a path from the lower concourse level to the auditoria. At the same time the shell vault to the side of the space, although there was a great deal of scaffold, represented a threshold to the space within the stage area. An entrance from the space between the shell vaults to the stage area was not designed, and the nearness to the stage would not be apparent in the completed building. The photography at the site has failed to explain the change in movement from the space between the shell vaults to the stage area. Again, in Display 10, groups of subjects responded to move through the space between the shell vaults. The architect has clearly intended this movement upon the exit from the auditoria. But the physical means was not provided at the time of photography.

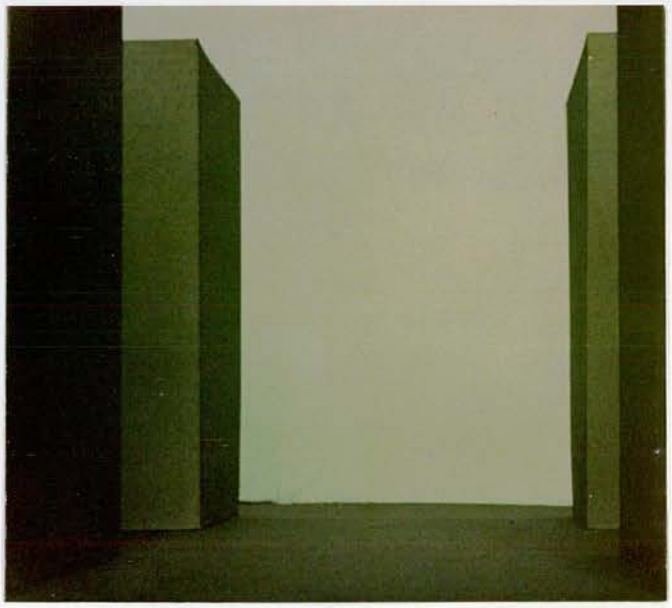
The forty subjects who have taken part in the experiments represented a range of architectural training in addition to variations of personality and general conditioning. The group of subjects was not a sample of the general population, and for this reason the average creativity score was considerably higher than the average for the general population.

A sample population obtained by random selection would need to be the basis for a factorial study of several hundred subjects. The present study has investigated factors that would be involved in the setting up of such a large scale factorial study, and from present conclusions, the writer would suggest the nature that a future investigation may take.

In Chapter I it was stated that the design of urban and architectural space initially provided paths for physical progression, but then exploited these paths to involve the perceptual systems of a subject. Stereoscopic photography would provide an appropriate method for the systematic variation of a space, or an element in space, from an abstract concept to a completed space. A stereopair of a model of an intersection of two paths is given in Fig. 68. By variation of the planes defining the paths it is possible to study changes of subjective responses to the abstract display. For example, in the stereoscopic viewing of Fig. 68 the subjective response may be movement and path. But as the importance of the transverse path is increased the display may become to be regarded as a barrier.



Left Image of Stereopair.



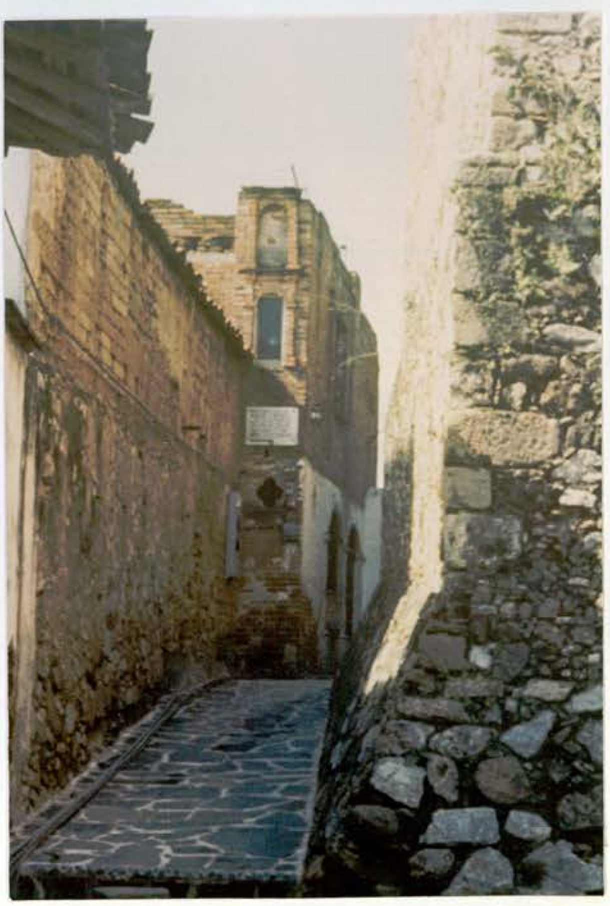
Right Image of Stereopair.

Fig. 68. Intersection.

In Chapter III the importance of binocular vision in the perception of architectural space was discussed. The work of Julesz in the perception of computer-generated patterns was cited to illustrate that the presence of visual cues was not essential for depth perception. A stereoscopic display of a path, Fig. 69, has been graphically reduced to an abstract stereoscopic display, Fig. 70. As the method involves the graphical preparation of each image, it is seen that systematic variation of a stereoscopic display is obtained without difficulty. The introduction of colour, texture, sunlight and shadow can be systematically provided in the display and subjective responses scaled for each variation. In this way visual cues are not independently isolated from their part in qualifying binocular vision, and the effect of their addition and subtraction to stereoscopic displays may provide a clearer understanding of the perceptual processes.

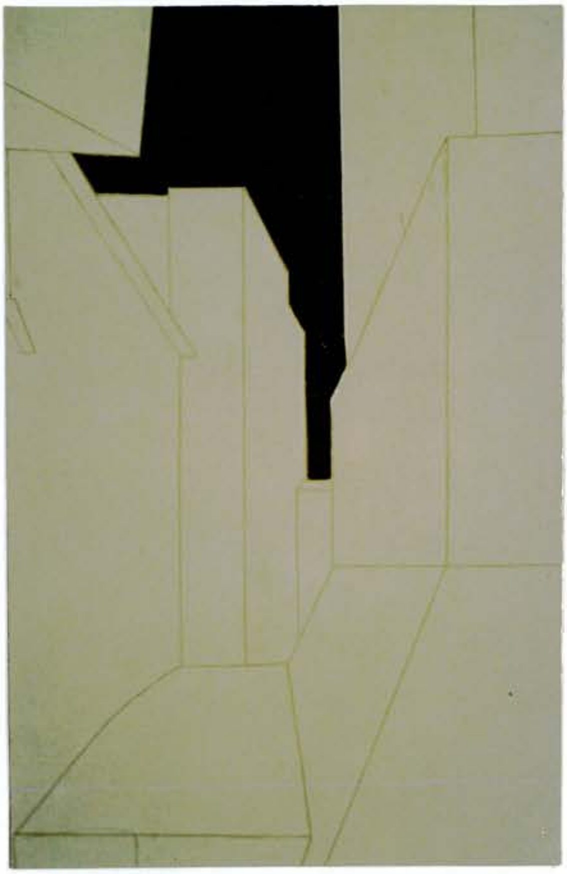
The study of repetition in viewing stereoscopic displays would not then be limited to the viewing of the same display and recording variation in subjective responses, stimulation, and time limits of tolerance. This study becomes a part of a wider investigation of variables that would be more closely connected to the design of spaces or elements in space.

Left Image of
Stereopair.

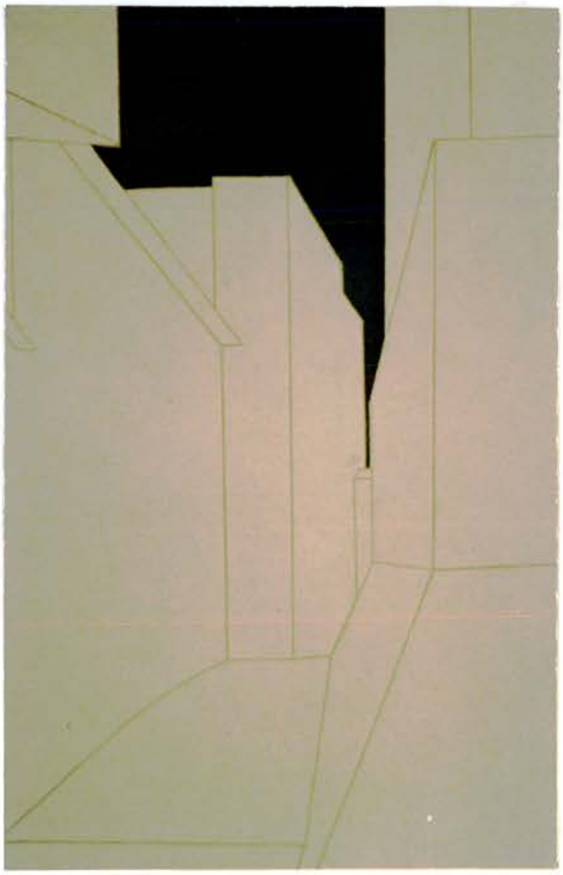


Right Image of
Stereopair.

Fig. 69. Path.



Left Image of
Stereopair.



Right Image of
Stereopair.

Fig. 70. Abstracted Display
of Path.

A future investigation of personality factors in the perception of architectural space could greatly facilitate the classification of subjects. In Chapter IX it was suggested that an appropriate measure of a subject in architectural space would be his awareness or perceptiveness to his surroundings. A factorial study could isolate factors of personality that correlate with perceptiveness in architectural space and this could eventually lead to the weighting of these factors in a specification.

A subject responds in some way to his environment and this response is dependent initially on sensory information. In this study the methods of stereoscopic photography have provided an appropriate means to represent spatial environment. The recording of eye fixations has provided quantitative evidences of subjective visual experience and these have been graphically represented. The classification of the personality of subjects has emphasized the need for a specific basis for classification directed to the perception of architectural space. A subjective response and stimulation analysis has provided an appropriate beginning for the classification of the individual experience of architectural space. And this classification would provide a basis for a factorial study of perception directed to a sample population.

BIBLIOGRAPHY

I. SPACE

Arnheim, R., Zucker, W. M., and Watterson, J.: 1966, "Inside and Outside in Architecture: A Symposium," Journ. Aesth. & Art Crit., 25:1, 3-15.

Collins, P.: 1965, "New Concepts of Space," Ch. XXIV., Changing Ideals in Modern Architecture, 1750-1950. London: Faber.

Perry, E.: 1965, "The Major Space," Prog. Arch., 46:6, 140-200.

/ Rasmussen, S. E.: 1959, Experiencing Architecture. London: Chapman & Hall.

Rowland, K.: 1966, "The Baroque Town," Ch. III., The Shape of Towns. London: Ginn.

Venturi, R.: 1966, Complexity and Contradiction in Architecture. New York: The Museum of Modern Art Papers on Architecture, I.

II. THE PERCEPTION OF SPACE

Borchers, P. E.: 1965, "Photogrammetrie et Architecture," Bulletin de la Societe Francaise de Photogrammetrie, 19, 73-89.

Bower, T. G. R.: 1966, "The Visual World of Infants," Sc. Amer., 213:12, 80-92.

Clark, B.: 1936, "An Eye Movement Study of Stereoscopic Vision," Amer. Journ. Psychol., 48, 82-97.

Deyo, B. V.: 1922, "Monocular and Binocular Judgment of Distance," Amer. Journ. Ophthal., 3:5, 343-347.

Ditchburn, R. W.: 1959, "Eye Movements and Visual Perception," Research (London), 9, 466-471.

Gregory, R. L.: 1966, Eye and Brain: The Psychology of Seeing. London: McGraw Hill.

Hallert, B.: 1960, Photogrammetry. New York: McGraw Hill.

Helmholtz, H. L. F. von: 1910, "The Theory of the Perception of Vision," Vol. III., Handbook of Physiological Optics. Transl. by J. P. C. Southall (1925). New York: Opt. Soc. Amer.

I. T. C.: 1964, Binocular Vision: Textbook of Photogrammetry, 4:2, Delft: International Training Centre for Aerial Survey.

Julesz, B.: 1960, "Binocular Depth Perception of Computer-Generated Patterns," Bell System Tech. Journ., 39:5, 1125-1162.

1964, "Binocular Depth Perception without Familiarity Cues," Science, 145, 356-362.

Kittler, R.: 1968, Some Spatial and Environmental Considerations of Architectural Design based on the Perceptual Phenomena of Vision under Daylight Conditions. Bratislava: Inst. Const. & Arch., Slovak Acad. Sciences.

Mackworth, N. H., and Bruner, J. S.: 1965, Selecting Visual Information during Recognition by Adults and Children. Harvard: Center for Cognitive Studies.

Vernon, M. D.: 1959, "Space Perception: A Symposium," Acta Psychol., 15, 258-269.

1966, Experiments in Visual Perception. Harmondsworth: Penguin.

III. THE REPRESENTATION OF SPACE

Gabor, D.: 1966, "Holography, or the 'Whole Picture'," New Scientist, 29, 74-78.

Halim, M. F. M. Abdel: 1952, "The Application of Stereoscopy to Architecture Studies," Part II., Unpublished M. A. Thesis, Univ. of London.

Halprin, L.: 1965, "Motation," Prog. Arch., 46:7, 126-133.

Leith, E. N., and Upatnieks, J.: 1965, "Photography by Laser," Sc. Amer., 212:6, 24-35.

Moretti, L.: 1952, "Spazio Strutture E Sequenze di Spazi," Spazio, 7, 9-20.

Rule, J. T.: 1941, "The Geometry of Stereoscopic Projection," Journ. Opt. Soc. Amer., 325-334.

Sokolov, P. P.: 1911, Autostereoscopy and Integral Photography by Lippmann's Method. (Russian). Moscow: Moscow State Univ.

Spottiswoode, R., and Smith, C. W.: 1952, "Basic Principles of the Three-Dimensional Film," Journ. Soc. Motion Picture & Television Eng., 269-286.

Spottiswoode, R., and Spottiswoode, N.: 1953, The Theory of Stereoscopic Transmission and its Application to the Motion Picture. Berkeley: Univ. Calif.

Thiel, P.: 1961, "A Sequence-Experience Notation," Town Plan. Review, 32:1, 33-52.

Valyus, N. A.: 1966, Stereoscopy. (Transl. Russian). London: Focal.

Zevi, B.: 1957, Architecture as Space. New York: Horizon.

IV. VISUAL DISPLAYS OF SPATIAL SEQUENCES

Borchers, P. E.: 1962, "A Three-Dimensional Record of Byzantine and Baroque Architecture," A. I. A. Journ., 37, 109-112.

Yarbus, A. L., and Goltsman, N. I.: 1955, "The Movements of the Eyes in the Perception of Images in a Stereoscopic Cinema," Transactions Inst. Biolog. Physics, I, 172-177. (Russian).

V. EYE MOVEMENT RECORDING

Carmichael, L., and Dearborn, W. F.: 1947, Reading and Visual Fatigue. Cambridge, Mass.

Clark, B.: 1936, "An Eye Movement Study of Stereoscopic Vision," Amer. Journ. Psychol., 48, 82-97.

Cornsweet, T. N.: 1958, "New Technique for the Measurement of Small Eye Movements," Journ. Opt. Soc. Amer., 48, 808-811.

Delabarre, E. B.: 1898, "A Method of Recording Eye Movements," Amer. Journ. Psychol., 9, 572-574.

Ditchburn, R. W.: 1959, "Eye Movements and Visual Perception," Research (London), 9, 466-471.

Dodge, R., and Cline, T. S.: 1901, "The Angle Velocity of Eye Movements," Psychol. Review, 8, 145-157.

Jacobson, E.: 1930, "Electrical Measurements of Neuro-Muscular States during Mental Activities, I., Imagination of Movement Involving Skeletal Muscles," Amer. Journ. Physiol., 91, 567-608. II., "Visual Imagination and Recollection," Amer. Journ. Physiol., 95, 694-702.

Jasper, H. H., and Walker, R. Y.: 1931, "The Iowa Eye Movement Camera," Science, 74, 291-294.

Judd, C. H.: 1907, "Photographic Records of Convergence and Divergence," Psychol. Review Monograph, 8, 370-423.

Kohlrausch, A.: 1931, "Elektrische Phänomena der Augen," Handbuch d. Nörmalen u. Patholog. Physiol., 12, 1393-1496.

Mackworth, J. F., and Mackworth, N. H.: 1958, "Eye Fixations Recorded on Changing Visual Scenes by the Television Eye Marker," Journ. Opt. Soc. Amer., 48, 429-435.

Mackworth, N. H.: 1962, "Eye Marker Camera," Indust. Design, 9, 38-43.

Marg, E.: 1951, "Development of Electro-Oculography," Arch. Ophthal., (New York), 45, 169-185.

Meyers, I. L.: 1929, "Electronystagmography: A Graphic Study of the Action Currents in Nystagmus," Arch. Neuro Psychiat., 21, 901-918.

Mowrer, O. H., Ruch, T. C., and Miller, N. E.: 1936, "The Corneo-Retinal Potential Difference as the Basis of the Galvonometric Method of Recording Eye Movements," Amer. Journ. Physiol., 114, 423-428.

Rodin, F. H., and Newell, R. R.: 1934, "Movements of Eyes under Cover," Arch. Ophthal., 12, 525-535.

Shackel, B.: 1958, "A Rubber Suction Cup Surface Electrode with High Electrical Stability," Journ. Applied Physiol., 13, 153-158.

1959, "Skin Drilling: A Method of Diminishing Galvanic Skin Potentials," Amer. Journ. Psychol., 72, 114-121.

1960, "A Pilot Study in Electro-Oculography," Brit. Journ. Ophthal., 44, 89-113.

1960, "A Note on Mobile Eye Viewpoint Recording," Journ. Opt. Soc. Amer., 50, 763-768.

1960, "Electro-Oculography: The Electrical Recording of Eye Position," Proc. III. Internat. Conf. Med. Electron., 323-334.

Shackel, B., Sloan, R. C., and Warr, H. J. J.: 1958, "Detector Plots Eye Movements," Electronics, 31:5, 36-39.

Smith, W. M., and Warter, P. J.: 1959, "Photoelectric Technique for Measuring Eye Movements," Science, 130, 1248-1249.

Sverak, J., and Peregrin, J.: 1963, "Contact Suction Electrode for Electro-Retinography," Vision Res., 3, 183-185.

Taylor, E. A.: 1937, Controlled Reading. Illinois: Univ. Chicago.

Tinker, M. A.: 1931, "Apparatus for Recording Eye Movements," Amer. Journ. Psychol., 43, 115-118.

Totten, E.: 1926, "Eye-Spots for Photographic Records of Eye Movements," Journ. Comparative Psychol, 6, 287-289.

VII. SUBJECTIVE RESPONSE

Arnheim, R., Zucker, W. M., and Watterson, J.: 1966, "Inside and Outside in Architecture: A Symposium," Journ. Aesth. & Art Crit., 25:1, 3-15.

Clouten, N. H.: 1967, "The Old Montgomery County Court House, Dayton, Ohio," Journ. Soc. Arch. Hist. (Amer.), 26:4, 294-300.

Cullen, G.: 1961, Townscape. London: Architectural Press.

Hall, E. T.: 1966, "The Anthropology of Space," Arch. Review, 140, 163-166.

Michelis, P. A.: 1964, "Some Reflections on Architecture," Journ. Aesth. & Art Crit., 23:1, 140-144.

Pevsner, N.: 1963, An Outline of European Architecture. Harmondsworth: Pelican.

VIII. CLASSIFICATION OF SPATIAL SEQUENCES

Cullen, G.: 1961, Townscape. London: Architectural Press.

Giedion, S.: 1964, "Jørn Utzon and the Third Generation," Zodiac, 14, 36-47.

Utzon, J.: 1959, "Ideas of a Danish Architect: Platforms and Plateaus," Zodiac, 10, 112-140.

1964, "The Sydney Opera House," Zodiac, 14, 48-86.

IX. CLASSIFICATION OF PERSONALITY

Allport, G. W.: 1938, Personality: A Psychological Interpretation. London: Constable.

Bass, B. M., and Berg, I. A.: 1959, Objective Approaches to Personality Assessment. New Jersey: Van Nostrand.

Burt, C.: 1939, "The Factorial Analysis of Emotional Traits," Char. & Personality, I, 285-299.

1948, "The Factorial Study of Temperamental Traits," Brit. Journ. Psychol., Stat. Sect., I, 178-203.

Buswell, G. T.: 1935, How People Look at Pictures: A Study of the Psychology of Perception in Art. Illinois: Univ. Chicago.

Cattell, R. B.: 1943, "The Description of Personality: I. The Foundations of Trait Measurement," Psychol. Review, 50, 559-594.

1943, "The Description of Personality: II. Basic Traits Resolved into Clusters," Journ. Abnorm. Soc. Psychol., 38, 476-506.

1945, "The Description of Personality: Principles and Findings in a Factor Analysis," Amer. Journ. Psychol., 58, 69-90.

1955, "The Objective-Analytic O-A Personality Factor Battery. Illinois: Inst. Personality & Ability Testing.

1965, The Scientific Analysis of Personality. Harmondsworth: Penguin.

Ed., 1966, Handbook of Multivariate Experimental Psychology. Chicago: Rand McNally.

Cattell, R. B., and Eber, H. W.: 1957, Handbook for the Sixteen Personality Factor Questionaire, Forms A, B and C. Illinois: Inst. Personality & Ability Testing.

Cattell, R. B., and Warburton, F. W.: 1967, Objective Personality and Motivation Tests: A Theoretical Introduction and Practical Compendum. Urbana: Univ. Illinois.

Drevdahl, J. E., and Cattell, R. B.: 1958, "Personality and Creativity in Artists and Writers," Journ. Clin. Psychol., 14, 107-111.

Eysenck, H. J.: 1940, "The General Factor in Aesthetic Judgments," Brit. Journ. Psychol., 31, 94-102.

1941, "'Type'-Factors in Aesthetic Judgments," Brit. Journ. Psychol., 31, 262-270.

1947, Dimensions of Personality. London: Kegan.

1952, The Scientific Study of Personality. London: Routledge & Kegan.

1960, The Structure of Human Personality. 2nd Edit. London: Methuen.

Ed., 1960, Experiments in Personality. Vol. II. London: Routledge & Kegan.

1961, "Eysenck on Cattell," Occup. Psychol., 35, 253-256.

I. P. A. T.: 1963, Data for Psychologists Selecting Students for Creativity and Research Potential. Information Bulletin 10. Illinois: Inst. Personality & Ability Testing.

Miller, J. C.: 1959, "Future Impact of Psychological Theory on Personality Assessments," See Bass, B. M., and Berg, I. A.: Objective Approaches to Personality Assessment.

Semeonoff, B.: Ed., 1966, Personality Assessment. Harmondsworth: Penguin.

Taylor, C. W., and Barron, F.: Ed., 1963, Scientific Creativity: Its Recognition and Development. (Univ. Utah Conferences on the Identification of Creative Scientific Talent, 1956, 1958, 1959). New York: Wiley.

Tolces, T.: 1956, Creative Discipline: Explorations in Awareness. Portland, Maine: Bond Wheelwright.

Thurstone, L. L.: 1931, "Multiple Factor Analysis," Psychol. Review, 38, 406-427.

1944, A Factorial Study of Perception. Illinois: Univ. Chicago.

1947, Multiple Factor Analysis. Illinois: Univ. Chicago.

X. CLASSIFICATION OF SUBJECTIVE RESPONSES AND STIMULATION

Carr, G.: 1966, "The Measurement of Meaning: Urban Design," Unpublished M. C. P. Thesis, Ohio State Univ.

Osgood, C. E.: 1952, "The Nature and Measurement of Meaning," Psychol. Bulletin, 49:3, 197-228.

1957, The Measurement of Meaning. Urbana: Univ. Illinois.