towards the individual empirical facts, as opposed to the
unidimensional approach which starts at the bottom of the
hierarchy of environmental knowledge and by a gathering of
numerous pieces of information works gradually upwards
towards an overall conception.

The final pupillary experiment was approached from a
conceptual point of view, in order to attempt to define the
subjective dimensions which might be affecting the pupillary
response.

Experiment 4: Factor analysis
The first step was to determine the factors which were
important in determining the subjects' subjective responses to
the visual stimuli used in experiment 2. The technique used
was factor analysis, which consists in extracting the
fundamental factors, determining the overall response from a
series of verbal rating scales.

Seven factors were obtained from the factor analysis:
1. A general affective factor,
2. An activity factor,
3. A comfort factor,
4. An intensity factor,
5. A femininity factor,
6. A happiness factor,
7. A coherence factor.

The highest correlation of factors to pupillary response
were, the femininity factor (correlation = 0.80), the intensity
factor (correlation = 0.65) and the happiness factor
(correlation = 0.65). But by far the most interesting finding
concerned the factor analysis itself. The first 'affective' factor
seems very closely related to the first factor found by Canter
[12,13] in four experiments carried out by him. These similar
first factors seem to constitute a common dimension, which
Canter identifies as a 'general factor of pleasantness' in
response to architectural stimuli. At the moment, the factor
suggests to me that people primarily deal with rooms as
coherent wholes; that they respond most strongly to spaces as
a unity rather than to discrete aspects. But obviously, this
requires a great deal of further study.

Conclusion
Rather than go back and sum up at all I have just described,
let me rather, go forward and attempt to pick out a path for
the future. I mentioned earlier. The drawbacks that I felt to be
inherent in the use of verbal or written responses, yet in
experiment 4 we made of a verbal scale (with all the
inherent misunderstandings, and nuances of meaning). There is
a conceptual technique which seems to me to progress beyond
the use of verbal scales, namely multidimensional scaling.
Rather than specifying dimensions to be studied (as in my
'complexity' experiments) or using verbal concepts, this
technique merely uses the concept of similarity or dissimilarity
as its starting point. Multidimensional scaling takes a total
environment (however defined) and, without the investigator
having to make any assumptions, or specifying any scales or
dimensions, out of the total environment it extracts the
important dimensions which affect people's subjective
responses to that environment. I hope that by now there is no
need for me to describe the usefulness of such a technique in
the study of behavioural responses to the built environment;
not only within architectural spaces, but also within urban
spaces; only its limitations have now to be found.

Points raised in discussion of paper
1. The main point made was the difficulty of determining
exactly what causes pupil dilatation. It was generally accepted
that the pupils dilate in response to physiological arousal but
whether that response is favourable or unfavourable is difficult
to determine.
2. It is known that physiological responses relate to one
another in a complex way and that there are great differences
between people in their physiological make up. It is therefore
all the more surprising that such distinct differences were
found between architects and non-architects.
3. It seems possible that the whole situation was of more
interest, or challenge to the architects and that this sexual is
what produced the results. Consequently, at this stage in our
knowledge the results tell us little about that nature of the
stimuli.
4. It was agreed that the studies indicate the potential value
of pupillary response measures as an addition to the battery of
measures for measuring human reactions to architectural
stimuli.

7 Visibility and privacy

Adrian R. Hill

Abstract: An experimental technique is described for the
simultaneous investigation of the opposing aspects of
vision-out (visibility) and vision-in (privacy) which allow for
subjective optimization. The results showed that people's
visual privacy needs vary systematically both with viewing
conditions and with individual personality factors.

Perceived or actual privacy?
In recent years the rapid growth of new towns and high
density housing schemes has indicated that the need for
understanding peoples' privacy requirements has become more
acute. For instance, in a questionnaire survey made at
Stevenage in 1965, Willmott [18,1] showed that complaints of
too high a density correlated fairly closely with complaints
that there was a disturbing lack of visual and aural privacy. But
the problem is complex, and it is no easy matter to establish
the underlying cause behind all complaints of privacy whatever
perceptual mode they relate to. Firstly, we must differentiate
between whether we are dealing with problems of perceived or
real privacy. By this, I refer to the distinction between how
much privacy a person feels he has, compared with the amount
of privacy that he actually has. There is a difference in
meaning here which is important to establish because the
aspect of privacy which we investigate will influence the
techniques we can use to measure it.

In the experiment which I shall describe in this paper I am
only concerned with the aspect of real visual privacy as it is
related to the problem of overlooking. This choice is based on
the assumption that, as people become more aware of their
surrounding environment (both physical and social) so their
judgements of perceived privacy are modified and approach a
level which is roughly equivalent to the real amount of privacy
present in a given situation.

Having selected the aspect of visual privacy in which I was
interested, I sought to establish a technique whereby I could
assess the extent to which people's privacy requirements
difficult depending upon such factors as the room function and the potential 'visual' intrusion into a room by an outside onlooker.

That privacy requirements differ depending upon the activity which takes place in a room is common knowledge. Furthermore, it is self-evident from a casual glance at the window screening in use around any high density housing scheme that people do not always aim to achieve maximum visual privacy. There is the prevalent desire to be able to see out of a window. Indeed, some designers are now suggesting that this may be the only function of windows (Markus [12.20]). But whatever the true function of a window, where there are problems both of outward vision and inward visual privacy, the designer needs to know whether he is dealing with two mutually exclusive attributes of the occupier's needs or whether he is concerned with a single value function of 'visibility'. I therefore set up an experiment in which the main aim was to test the hypothesis that the desired levels of outward vision and inward visual privacy were opposing requirements of the single value function or perceptual mode of 'visibility'.

A problem of optimization

Put this way, we have the embryo of an optimization experiment in which maximum visual privacy would be achieved by having no window at all, and maximum outward vision would be achieved where there were no intervening object between an occupant and the view. The interpolation of any object in the window aperture therefore interferes with one fundamental function of the window -- and that is to allow vision through it and thus maintain a visual link between the building occupants and the outside. On the basis of this argument the choice of an independent variable for the optimization experiment was influenced by the way in which the majority of building occupants themselves appear to obtain a crude solution to the problem of outward vision and privacy -- and that is by using various types of window screening materials in the form of blinds or curtains. A traditional and commonly used material for this purpose is the net curtain, since it will allow vision through it only if certain geometrical and brightness conditions are satisfied. By exploiting this characteristic of fine open weave, mesh materials the experimental procedure involved nothing more than asking an observer to chose what was considered to be the 'best' mesh material for a particular combination of outside view and visual privacy requirements. Essentially the experiment could be called a sophisticated investigation of the Victorian net curtain effect!

Means of selecting an optimum

A mesh material can affect the amount of vision through it in a number of different ways, by changes in such factors as thread thickness, weave density, weave orientation, and so on. The relationships between eleven such factors were studied in an earlier experiment (Hill and Markus [12.21]) from which the most potent factor affecting through vision was chosen for the present investigation as a means of effecting a balance between outward and inward visibility. Clearly, the higher the solid to void ratio of the weave, the more difficult it is to see through the material and hence it can be assumed the greater the visual privacy it affords. By obtaining a number of mesh samples which differed only in respect of solid to void ratio it was possible, therefore, to obtain a simple measure of an observer's privacy and/or outward visibility requirements in terms of the mesh weave density.

Description of apparatus

The essential part of an optimization experiment is that an observer has an equal knowledge and control of both the conflicting requirements. In this experiment, therefore, it was necessary that the observer (i.e., the building occupant) had equal information about both outward and inward visibility. These conditions were fulfilled by a specially designed laboratory apparatus which is shown in plan form in Figure 7.1.

The observer was seated at a distance of 1.8 m from a grey wall surface in which were placed two window apertures approximately 600 mm sq. Direct outward viewing was through the right-hand window aperture at a coloured photograph of an outside view back-projected on to a translucent screen. Inward viewing was permitted via the left-hand window aperture and the two angled plane mirrors placed between the wall surface and the projection screen. By looking into the right-hand mirror, the observer saw an image of himself as though being observed by an outside onlooker at a distance of 6 m from the window. Direct simultaneous comparison of outward and inward visibility was therefore possible.

By means of a pulley system the observer controlled the choice of mesh sample in the two window apertures from six different solid to void ratios ranging in optical transmittance from 44-90%. These six meshes were joined in a roll of continuously increasing weave density and mounted on rollers at the back of the window aperture. The mesh surfaces were illuminated by spotlights which were positioned to avoid undue stray light falling on to the projection screen. The mean mesh surface luminance, measured from the back of the left-hand window aperture and from the front of the right-hand window aperture, was approximately 25 cd/m².

![Fig.7.1 Plan of apparatus used in optimization judgements of outward vision and visual privacy](image-url)
The observer was illuminated by a floodlight placed to the left of the entire apparatus such that the luminance of a standard white MgO block placed at the observer's eye was approximately 9 cd/m².

Since the experiment was only aimed at establishing the feasibility of demonstrating an optimum solution in terms of outward and inward vision by the selection of a mesh screening material, it was considered desirable to choose a number of different viewing conditions which, by hunch, could be expected to give markedly different responses to the visibility requirements. For convenience, the two main experimental variables were the outside view and the inside room function. Two outside views were used: one was a photograph of a nearby pedestrian walk in which the privacy requirements were expected to be fairly high, and the other was a photograph of a more open area in which the privacy requirements could be considered to be less stringent. For simplicity I will call this latter view a 'landscape-type view'.

The two room functions included in the experiment were imaginary since it was difficult to achieve an adequate representation in the laboratory. These were stated to be a kitchen-dining room and a ground floor bedroom in a bungalow, and none of the observers expressed that these conditions were difficult to visualize in the experimental set up. Essentially, therefore, the experiment was a 2 × 2 factorial design involving two outside view conditions and two inside room functions, thus making a total of four treatments for each of which optimum viewing solutions could be obtained in terms of mesh weave density.

Observers
In the interests of realism, all the 30 observers used in this experiment were housewives currently living in Cumbernauld New Town, where stringent privacy requirements were considered to be particularly prevalent because of the high density housing. Their ages ranged from 28 to 36 years. When volunteering, none were aware of the exact aims of the experiment since they were told simply that the experiment was part of a series of projects concerned with problems of design and layout of houses in new towns. In other words, they had no prior indication that the experiment was concerned with aspects of privacy.

Method
Before any observations were made, a standard set of instructions was read to each observer. This indicated that they were to imagine themselves sitting in a room, looking out through the window directly in front of them, and that the mirror on the right of the window aperture showed what a person from outside would see when looking into the room at a distance of about 6 m from the window. In other words, this was the view of themselves sitting in the room as would be seen by an outside onlooker looking in from the outside. The total range of available mesh materials was then demonstrated to each observer so that they were familiarized with the limited choice from which they were required to select one material which they considered to be the best for a given room function and outside view combination.

Each observer made two judgements on all of the four treatments, the first by starting at one, and the second by starting at the other of the extreme limits of the range of mesh densities. The changeover point in an observer's implied judgements of visibility and privacy was then considered to be the optimum (i.e., the 'best') material under the prevailing conditions of viewing, thus expressing a satisfactory compromise between the opposing requirements for outward and inward vision.

Half the observers made their initial judgements using a kitchen-dining room with a landscape-type view, and the other half commenced with the combination of a ground-floor bedroom in a bungalow with a nearby pedestrian walk. Any measured differences in the 'best' choice of mesh between these two conditions would demonstrate the reliability of the technique.

Results
An F test on the data for initial judgements, in the two conditions to which reference has just been made, was significant at p = 0.01. This showed that there was a greater variance in the selection of an optimum mesh density for the bedroom with pedestrian walk condition than for the kitchen-dining room with landscape-type view. It would seem, therefore, that where privacy requirements are expected to be high there are fairly large differences in the needs of different individuals. A Mann-Whitney U test (see Siegel [6,1]) also showed that observers gave significantly different solutions for the two initial treatment combinations (p < 0.001), indicating as one would expect, that the greater privacy requirements were obtained for the bedroom with pedestrian walk condition. The success of these results clearly demonstrated that it was possible to make manifest simple optimization judgements which are otherwise concealed property of the

<table>
<thead>
<tr>
<th>source of variance</th>
<th>sum of squares</th>
<th>degrees of freedom</th>
<th>mean square</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room function</td>
<td>176.7</td>
<td>1</td>
<td>176.7</td>
<td>220.8</td>
<td>0.001</td>
</tr>
<tr>
<td>View</td>
<td>33.9</td>
<td>1</td>
<td>33.9</td>
<td>42.4</td>
<td>0.001</td>
</tr>
<tr>
<td>Room function × view interaction</td>
<td>23.7</td>
<td>1</td>
<td>23.7</td>
<td>29.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Groups (initial judgements)</td>
<td>5.1</td>
<td>3</td>
<td>1.7</td>
<td>2.1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Observers</td>
<td>94.7</td>
<td>29</td>
<td>3.3</td>
<td>4.1</td>
<td>0.001</td>
</tr>
<tr>
<td>Replications within observers</td>
<td>1.1</td>
<td>1</td>
<td>1.1</td>
<td>1.4</td>
<td>n.s.</td>
</tr>
<tr>
<td>Error</td>
<td>166.0</td>
<td>203</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>500.2</td>
<td>230</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The inter-observer difference, although significant, represented only a very small fraction of the total variance in the data. The three different women's social organization groups from which the observers were obtained (indicated by the 'groups' effect) had no significant effect on the results, thus indicating homogeneity of the population sample.
observer, and that the data was not purely an experimental artifact.

The total data was, therefore, subjected to an analysis of variance in order to determine the relative effects on the choice of an optimum of the two variables—room activity and outside view. A summary of this analysis is shown in Table 1. This shows that by far the largest source of variance was due to the room function factor. When the data is further partitioned it reveals the expected results; namely that the privacy standards in the bedroom were much greater than those in the kitchen-dining room, and also that observers showed a greater desire for outward vision with the landscape-type view than with a nearby pedestrian walk. Although the interaction between room function and view is shown as significant in this analysis the effect was fairly small because the error variance in the data itself is fairly small. This effect is shown in Figure 7.2 where it can be seen that the difference in privacy requirements between a nearby pedestrian walk and landscape-type view are slightly more marked in the bedroom than in the kitchen-dining room situation.

Before making the optimization judgements, each observer completed an Eyenrook Personality Inventory so that the effect of certain personality characteristics on the choice of mesh could be examined. The personality scores were dichotomized into both high and low E and N scores. An analysis by the Median Test showed that observers with high E (more extroverted) scores consistently chose a higher mesh weave density. The difference was significant at \( p = 0.05 \), which indicates that extroverts have higher privacy standards than introverts. No significant difference was found for the optimum visibility level when the data was split for high and low N (neuroticism) scores.

Very little information seems to be available on the relationship between personality and privacy, but some work carried out under David Walters a few years ago at Birmingham School of Architecture did show a weak positive correlation between an attitudinal measure of visual privacy and the EPI extroversion score. So it would seem that extroverts feel more conscious of a need for visual privacy than do introverts.

Solutions, therefore, to the visibility problems in window design can at best only be first approximations towards an optimum solution if based upon the requirements of a particular room function and outside view. If the design aim is towards a complete satisfaction of the user occupant then it would seem necessary to take into account factors other than those specific to the physical environment. However, despite these interesting side issues arising out of the experiment, its main value has been in demonstrating that the aspects of outward vision and real visual privacy are opposing requirements of the single value function, visibility. In other words, they may both be expressed in terms of the same measurable quantity which, in the present context of net curtains, is some form of a person's ease of seeing through the materials.

Hence, the development of this type of experiment is dependent upon the establishment of a scale that will measure different levels of visibility through a mesh. Work carried out by Hill and Markus [12.21] has gone some way towards developing such a scale and further work by Hill [12.22] has shown the conditions under which the scale must be used if effects due to context are to be avoided.

The future?

A pertinent question to ask of this experiment is, what has it to offer to the designer or architect who is faced with a problem of window design? The answer at present must be that the results provide little in the way of tangible data which is directly applicable to real design problems. It would be premature and almost absurd to suggest otherwise. Nonetheless, the value of the experiment so far has been in demonstrating that it is possible for naive observers to make simple optimization judgements; to select a compromise between outward and inward vision. We have also seen how this optimization technique is capable of showing differences in visual privacy requirements not only according to the room function and outside view conditions, but also in terms of the occupant's personality. Much more experimentation is required, however, involving a refinement of the scaling techniques used both in the laboratory and in the field before any data can be offered in the terms of a design guide on visibility and privacy.

In tackling the problem in the manner just described, albeit in a laboratory situation, the aim has been to show that the aspects of outward vision and visual privacy are not such intangible aspects of window design as they may appear to be at first sight, and it should not be too long before they can receive a more rational consideration alongside the many other more clearly understood aspects of environmental design.

Acknowledgements

I would like to express my thanks to Professor Thomas A. Markus whose ideas and comments have provided much of the inspiration behind this work. Acknowledgement is also due to the Science Research Council which financed the experiment as part of a larger study on 'Vision through meshes', and also to Fothergill and Harvey Ltd for having supplied the specially woven meshes.
Points raised in discussion of paper
1 It was agreed that the term 'visual privacy' was used in the paper in a much narrower sense than is commonly the case when it is used by architects.
2 It was also pointed out that the conditions for good visibility and visual privacy are not constant throughout the day and that people do exert control over their levels by other means such as drawing curtains.
3 It was suggested that, in the light of these findings, a further study of the visibility properties of net curtains would be of value.

8 Differences between full-size and scale-model rooms in the assessment of lighting quality

J. J. H. Lau

Abstract: The use of reduced scale physical models in research into lighting quality is discussed. An experiment is described which examined the difference, when assessing the quality of lighting, between full-size mock-ups and scale models of a study bedroom. Using paired comparisons, subjects assessed either the mock-up or the model on one of two criteria - pleasantness and gloom. Results indicated that the two modes of representation were assessed in a similar manner.

Pleasantness in lighting
There is a growing impetus in lighting research to quantify aspects of lighting quality, spurred on by the knowledge that horizontal illumination alone is not adequate as an indicator of the adequacy of light in an interior. For many years, a committee of the Comission Internationale d'Eclairage has been looking at the problem of 'pleasantness in lighting'. The committee found that it was very difficult indeed to define the problem, let alone measure it. This impasse is probably due in some degree to the lack of an appropriate measure of the adequacy of light. Recently, Logan et al. [12.23] popularized an old idea that if light is measured in the same way as temperature, i.e., as a physical quantity, it may be more representative of the subjective feeling of adequacy of light. Indeed, Epeneshko and Sidorova [12.24] indicated that both mean cylindrical and mean spherical (scalar) illumination is a much better indication of the adequacy of light than mean horizontal illumination. Following these studies on adequacies of light and a later study on modelling index (Cuttle et al. [12.25]), there seems to be renewed hope and greater effort in pursuing the problem of 'pleasantness in lighting'.

The use of models
In the investigation of lighting quality, and indeed in lighting design when the qualitative aspects are to be appraised, there is a general preference for reduced scale physical models, because of convenience and ease of manipulation. Scale models have often been used to convey the 'architectural qualities' of buildings and interiors — sometimes as a design tool but perhaps more often as an aid for 'selling' an idea to the client. Despite general and widespread usage of scale models, little is known of the implication of a reduction in physical size. The so-called 'scale effect' referred to by Hopkinson [12.26] is not well understood. Reduced scale seems to enhance the quality of the object or building interior represented, often turning a possibly mundane item into an object of fascination and beauty. Though certain 'rules' have been formulated for the use of scale models, little work has been done to validate experimental work carried out using scale models or the effect on validity of the degree of crudity or accuracy of simulation. As the continuing use of scale models for lighting quality assessment is likely, further experimentation on model validity would seem justified.

Pleasantness and gloom
In the experiment to be described, two criteria of assessment are used — pleasantness and gloom. The problem of 'pleasantness' in lighting, as mentioned earlier, has been the interest of the Comission Internationale d'Eclairage for some time. Though little definitive work has been done in the area of subjective lighting, the use of the pleasantness-unpleasantness continuum has a relatively long history in psychology and a substantial amount of experimental work has been carried out (Bopshe-6erber [1.14]). From earlier work (Lau [12.27]), there is an indication that gloom (in the context of a description of a room) results not only from a combination of physical entities but also a complex interaction of the individual with the physical environment. As the concepts of gloom and pleasantness may be said to be somewhat opposed to each other, assessments using both of these concepts would have a better opportunity of covering a wider spectrum of factors related to model validity in the appraisal of subjective lighting than would otherwise be the case.

The experiments
The investigation, part of a larger investigation, is essentially two experiments — the first being the assessment of pleasantness and gloom (on separate occasions and using different observers) using full-size rooms, and the second a repeat experiment using scale model rooms. Sixty-four observers took part in the experiments. Twenty observers assessed pleasantness using full-size rooms and twenty assessed pleasantness using scale model rooms, eight assessed gloom using full-size rooms, and sixteen assessed gloom using scale model rooms. Observers were asked to assess different lighting arrangements for a single study-bedroom using the technique of paired comparison on the two continua mentioned. Two full-size mock-ups and two one-sixth full-size scale models of study bedrooms were constructed and arranged as illustrated in Figure 8.1.

The ceilings of the rooms were painted white and the walls grey (Munsell notation 2.5Y6/0.5) with a measured reflectance of 25%. The floor finish was of grey linoleum with approximately the same reflectance as the walls. The arrangement of the furniture and fittings was as illustrated in Figure 8.2.

An observer may enter either one of the rooms, and they were interconnected to facilitate paired comparison. The models were mounted flush on the walls of the full-size rooms, this was to allow for future experiments in which the full-size room may be compared directly with its scale model counterpart. When the models are not required, they are hidden from view. In order to prevent light from the room from reaching into the model during assessment, hinged panels with viewing apertures were provided and these in addition provide a standard eye height for viewing of the models.