EXPERIMENTAL STUDY ON THE INFLUENCE OF THE SPATIAL DISTRIBUTION OF GRAINS ON THE GRAININESS OF PHOTOGRAPHIC FILMS

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An experimental investigation has been conducted to determine the influence of the spatial distribution of grains on the graininess of photographic films. This has been done using model photographic films and a psychometric method of assessment of graininess. It has been shown, within the inherent limitations of the present experiment, that the spatial distribution of grains significantly influences the perception of graininess.

The perception of non-uniformity in a photographic reproduction by an observer (who views the photographic reproduction) is termed graininess. Graininess is therefore a purely subjective concept. The spatial inhomogeneities in the developed image that give rise to the sensation of graininess can be described in terms of the spatial variations of the transmitting or the reflecting characteristics of the image. This appearance of inhomogeneity in the image is produced not only by the presence of the individual grains but also by the existence of a pattern resulting from the spatial distribution of grains. When, as a result of this distribution, a number of grains lie close together, they appear to the eye as a black clump or, when there is a local scarcity of grains, as a hole. The clumps and holes are themselves of various shapes and sizes and are variously distributed. The objective appearance of the inhomogeneities which give rise to the subjective impression of graininess is termed granularity. Various methods have been suggested for the measurement of graininess and granularity by different workers, and quite a few attempts have been made to obtain a satisfactory correlation between the objective concept (granularity) and the subjective concept (graininess). Many workers have sought to avoid the difficulties of direct psychophysical evaluation of this image inhomogeneity by resorting to purely objective methods of measurement, and much effort has been directed towards the development of instruments and techniques which are expected to give values in direct agreement with visual appearance.

For measuring graininess an instrument has been used by Jones & Deisch[1] which projects a magnified image of the developed photographic deposits on a magnesium carbonate screen and this image is viewed at different distances by means of a mirror arrangement. The viewing distance at which the image on the screen appears homogeneous, is termed blending distance, and this is taken as a measure of graininess. This instrument as modified later by Hardy & Jones[2] is cumbersome and owing to the presence of the diffusing screen, the maximum obtainable field luminance is low. To overcome these disadvantages, a graininess instrument was built by Lowry[3] in which the observer views an aerial image formed by a lens and the luminance of the field can be made appreciably higher than that in the Jones-Deisch instrument. Moreover, the field subtended at the eye by the lens remains practically constant throughout the entire scale of the instrument, and the blending distance also remains essentially fixed, so that graininess is measured in terms of blending magnification. Jones & Higgins[4] also designed an instrument to measure graininess in terms of the reciprocal of the blending magnification of an image of the sample as viewed by binocular vision from a constant distance. The value of graininess with the blending magnification instrument is obtained by dividing the blending magnification into an arbitrary constant 1,000, so that graininess values thus obtained increase as the graininess of the sample increases. This instrument is essentially an autofocus variable magnification projector which forms an image of constant size and of a luminance which is proportional to the transmittance of the sample.

In all these methods, a measure of graininess is obtained either in terms of blending distance or in terms of blending magnification. These quantities obviously depend on the size-frequency distribution of grains apart from other determinants such as contrast, development condition, etc. The assumption of the dependence of graininess on spatial distribution of grains is implicit in almost all objective evaluation of granularity as in the experiments cited above, but this factor has not been singled out for exclusive study to observe to what extent and how graininess depends upon spatial distribution of grains. If the dependence is a major one, then in the objective specification of granularity some measure of this spatial distribution of grains should be included. In the commonly used methods[5,6,7] of specifying granularity no special attention is paid to the spatial distribution of grains.

In the present investigation an attempt has been made to find the relation between the spatial distribution of grains and graininess. In the perception of graininess the main determinants are (*i*) size-frequency distribution of grains and (*ii*) spatial distribution of grains. A third one, which is effective in a lesser degree, and in particular cases only has be to considered in a study aiming at a complete description of graininess or, granularity. This is the practically uniform distribution of relatively smaller grains. This under certain conditions of viewing may give rise to the impression of a non-uniform texture. In the present study the assumption has been made that the general obtrusive effect is due entirely to the relatively bigger grains. No exclusive attention has been given to the smaller grains except rather indirectly in that, in the size-frequency distribution, these grains have also been considered. The difficulty of the present study is that actual photographic materials having the same statistical properties but different spatial distribution of grains are not available in a sufficiently large number to make experimental evidence conclusive. This difficulty was by-passed by resorting to model photographic materials in which the spatial distribution of grains could be changed at will without changing the statistical properties of the grains.

EXPERIMENTAL PROCEDURE

The method consists in determining psychometrically the graininess in several photographic reproductions of model photographic materials in which the statistical properties of the size-frequency distribution of grains were kept unaltered, but the spatial distribution of grains was altered. The standard deviations of grains and grain-clumps in all of the reproductions were determined using a physical method in order to verify whether or not the statistical properties of grains were the same in all the reproductions evaluated psychometrically.

Preparation of model photographic materials

In the preparation of model photographic materials (9 in all) the same model grains were used but their spatial distributions were different. In actual photographic materials the grains are of various shapes and sizes, but it is usual to assume in studies such as the present one that the grains are spherical. This assumption is only approximately valid. Any other assumed shape would have the same objection and from practical point of view a spherical shape is a convenient one. In photographic reproductions the grains usually appear to the observer as two dimensional extensions, unless special methods of observation are used. Hence the model grains were taken as circular plates of thickness small compared to the diameter of the circle. The model grains were prepared from sheets of stiff paper of about 0·25 mm thickness by cutting from them circular discs of different diameters. The size-frequency distribution of the grains was assumed Gaussian[8],

$$G\ (x) = e^{-x^2/2a^2} \tag{1}$$

Here $G(x)$ represents the number of grains of size (diameter) x and a is the standard deviation. To calculate $G(x)$, the standard deviation of model grains was taken as 10 mm. This value was chosen in conformity with the various relevant magnifications so that in the final prints, as presented to the judges for psychometric evaluation, the standard deviation was about 1·00 mm, a size which is close to the value found by Higgins & Jones[9] for convenient observation of developed grains. To find the numbers of grains of different diameters it was rather arbitrarily assumed that in a given collection of grains, the number of the largest grain was one, ie, $G(x) = 1$. This gave $x = 21{\cdot}45$ mm. The relative numbers of grains of ten different diameters (3, 5, 7, 9,........21) were then determined from a plot of the equation (1) using the standard method.

To find the total numbers of grains of different diameters that formed the final collection of grains, the area on which the model grains had to be spread was then determined. This area was approximately 40,000 sq cms on a white sheet of drawing paper. The total number of grains of all sizes which would have to be spread to cover the said area was then determined. To find this total number it was assumed that about half of the total area was to be covered by the grains and about half was to be left uncovered as blank spaces between grains and grain-clumps; and that the numbers of grains of different sizes as already found were to be increased in the same proportion for all sizes to form the final collection. Thus the number of grains of each size in the final collection was determined.

Nine distribution matrices which formed the frame of reference for nine different spatial (planar) distribution of grains were chosen. The grains were then distributed on a drawing paper fixed to a drawing-board according to one of these matrices in as random manner as it was possible within the requirements of the particular distribution and the whole was kept on the floor and uniformly and sufficiently illuminated. The illumination was so controlled that the contrast between the grains and the background was reasonably low. A photograph of this was taken with the camera held downwards from a rigid support. The photograph was taken on fine grain film and the camera magnification was 25÷. This procedure was repeated for each of the remaining eight spatial distributions of grains while the same grains and the same camera under the same focussing condition were used.

All the nine negatives were developed simultaneously under controlled conditions. A positive reproduction of one of these model photographic materials is shown in Fig. 1.

Psychometric evaluation of graininess

The psychometric evaluation of graininess was done according to Guilford's paired comparison method as discussed by Som & Ghosh[10]. Positive contact prints of the negatives, all made under identical optical and photographic conditions, were presented to forty judges for evaluation. The inherent graininess of the film on which positive prints were made was imperceptible. The positive prints were made at a magnification 2·5 X. Hence the total magnification of the grains as presented to the judges was 10÷. Thus the standard deviation of the grains in the positive print was 0·1 mm. The detailed procedure of judgment and the method of evaluation of graininess from the judgment data have been discussed in the reference cited above[10]. The same procedure was followed. The psychometric scale values of graininess have been presented in Table 1 for all the prints.

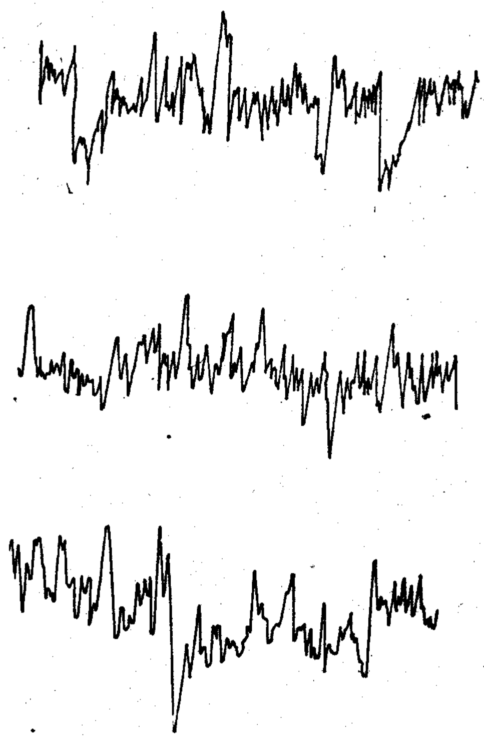

Fig 1—Microphotometer traces of three different negatives

Determination of the standard deviation of grains and grain-clumps

As a convenient statistical parameter of grains and grain-clumps as photographed on the negatives (the model photographic materials) the standard deviation of light transmittance through the negatives was determined. (It is to be noted that the clear spaces in the negatives corresponded to the appearance of grains and grain-clumps in the positives presented to the judges for judgment, and both corresponded to the distribution of

TABLE 1

PSYCHOMETRIC SCALE VALUES OF GRAININESS

Print No.	Psychometric scale values of graininess	Print No.	Psychometric scale values of graininess
1	90·21	6	82·12
2	68·13	7	49·20
3	100·00	8	54·60
4	57·54	9	55·90
5	68·38		

model grains on the drawing paper). For this purpose a non-recording Hilger microphotometer and Sargent recorder were used. The recorder was fitted with an integrator. Electrical power to microphotometer lamp was supplied through a trickle charger to ensure stability of the lamp output. Light from the lamp was focussed by the lower microscope objective of the microphotometer on the negative under measurement. The negative was mounted on a specially designed mount which could be moved across the light path by the synchronous motor driven shaft of the microphotometer. The mount was so designed that the negative could be rotated in its place through angles of 45°. The transmitted light beam was taken up by the upper objective and focussed on to a circular aperture of 0·034 mm in diameter placed in front of the photomultiplier. The photomultiplier output was fed to the recorder and the integrator of the recorder was also put into operation. The integrator was used with a view to obtaining the area under the trace simultaneously with the trace. The magnification of the upper objective was 13 X, so the effective diameter of the scanning aperture was about 26 μ (a value which was very small compared to the standard deviation of grains on the negative).

The mean transmittance line of the microphotometric trace could be found from the area under the trace and the length of the trace. The deviations of transmittance from this mean line were determined and the relative deviations of transmittance found as the ratio $\triangle T/T_m$, where $\triangle T$ is the deviation of transmittance and T_m is the mean transmittance. The standard deviation of transmittance fluctuations could then be determined using the standard procedure.

On each of the nine negatives the scanning was done along three directions, two of which were mutually perpendicular and the third was inclined at an angle of 45° to the mutually perpendicular directions. The scans were all obtained under indentical conditions and for each film standard deviations were found for each of the three directions of scan. The mean standard deviations for the films have been presented in Table 2.

TABLE 2

MEAN STANDARD DEVIATION FOR THE FILMS

Film No.	Mean standard deviation	Film No.	Mean standard deviation
1	·2533	6	·2729
2	·2716	7	·2568
3	·2550	8	·2643
4	·2736	9	·2733
5	·2706		

CONCLUSION

From the results of the experiment as tabulated in Tables 1 and 2 (Print Nos. in Tables correspond to film Nos. in Table 2) it is seen that the psychometric values of graininess vary over wide range while the standard deviations of grains and grain-clumps are almost constant. It is believed that the slight-variation in the standard deviation-values can be accounted for by the finite number of directions of scan (3 in the present experiment) and the variation can be reduced by increasing this number. However, it does not seem possible that the observed variation in standard deviations can account for so large a variation in the psychometric scale values. Hence, within the limitations of the present experiment, it can be conclusively stated that the spatial distribution of grains contributes largely to the graininess of photographic films. The way in which this contribution is entered into the perception of graininess by the observer is uncertain and does not seem to be emenable to objective analysis. However, it seems possible that certain physical of the spatial features distribution of grains may be studied and if necessary, entered as a separate factor or otherwise into a satisfactory description of graininess.

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