Title
Visual contrast thresholds for large targets. Part II, The case of high adapting luminances

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Publication Date
1960-06-01

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VISUAL CONTRAST THRESHOLDS FOR LARGE TARGETS

Part II: The case of high adapting luminances

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June 1960
Index Number NS 714-100

SIO REFERENCE 60-31

Bureau of Ships
Contract NObs-72092

Project S F001 05 01

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Summary

Systematic data relating target size to the contrast necessary for detection at various levels of adapting luminance have heretofore been limited to 6° and lower. In many practical situations, however, larger target subtenses are involved, and the solution of visibility problems by established nomographic means has been impossible owing to lack of input visual performance data for large targets. The hypothesis has been advanced that the limiting target situation might reasonably be equivalent to the instance in which the entire visual field is divided, as it becomes fatuous to speak of targets larger than can be accommodated in the binocular visual field.

An experiment was performed which yielded data for both the upper limiting circular target size of the previously used data of the Tiffany research (6°) and for a "split field" in which the target comprised a luminance increment on one half of the visual field. Six levels of background luminance were studied; those for which the classical data had not reached a terminal value of contrast.

The curves of Blackwell (2) have been provisionally extrapolated to limiting contrast asymptotes on the basis of the experimental results obtained by the Visibility Laboratory.

VISUAL CONTRAST THRESHOLDS FOR LARGE TARGETS

Part II: The case of high adapting luminances

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Introduction

Part I of the present report described an experiment designed to extend the useful range of visual performance data regarding contrast threshold to very large target sizes, and presented graphical interpolations which enable the estimation of thresholds for any large target of interest up to a limiting, asymptotic value which cannot physiologically be exceeded owing to the structure of the human visual apparatus. (1) The data presented were suitable for the direct extension of the published curves of Blackwell (2), and Figure 1, however, only at scotopic levels of adapting luminance (10^{-4} and 10^{-5} foot-lamberts). At higher background levels (10^{-3} up to 10^{0} foot-lamberts), the data for 6° uniform circular targets of positive contrast showed a consistent departure from the Blackwell values for threshold contrast, being higher in all cases. These differences were tentatively ascribed to the fact that our experiment was conducted using a uniform target duration of six seconds, while the Blackwell data are for presentation times which were variable and reached, in some cases, more than 30 seconds. The obtained discrepancies

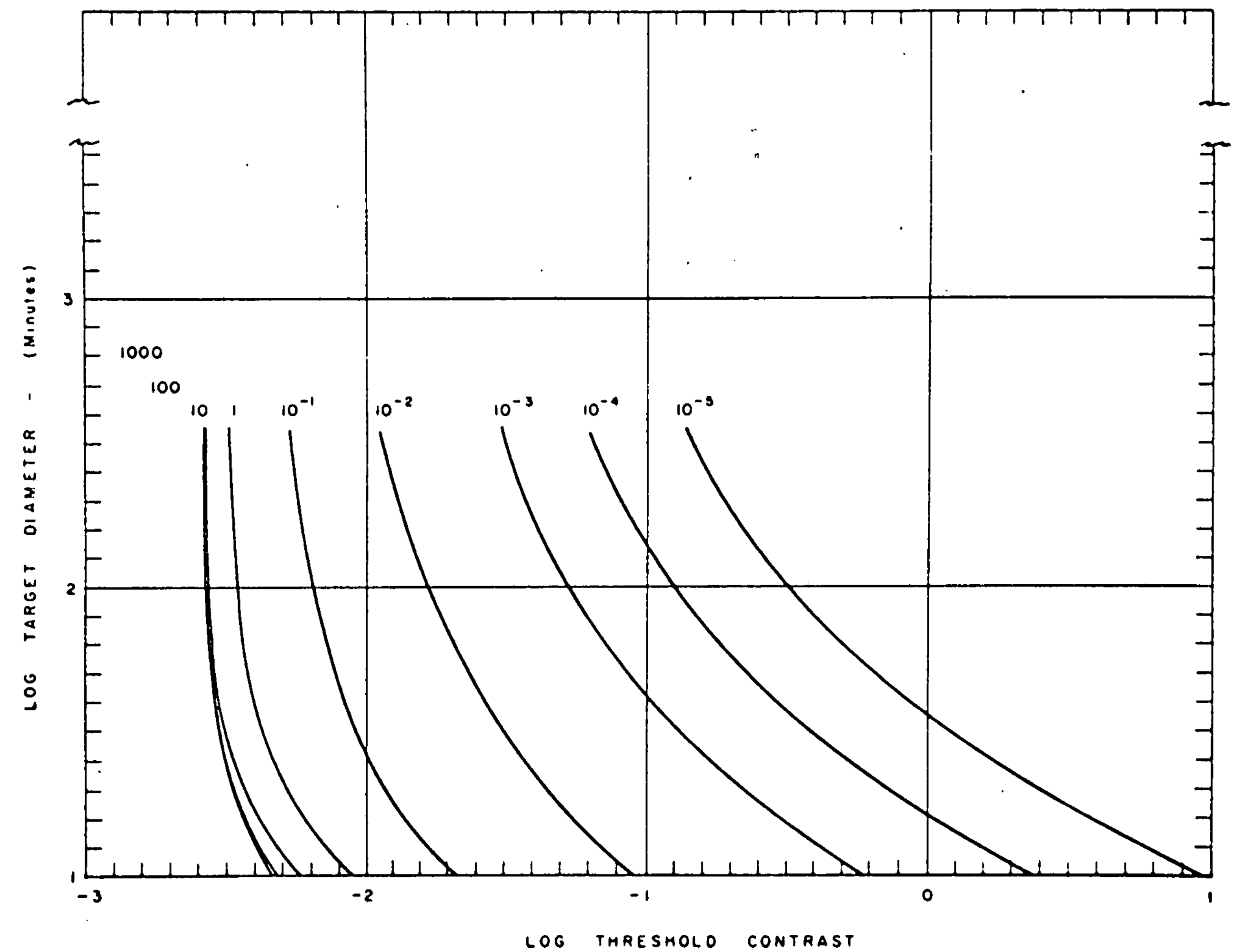

Figure 1

Contrast thresholds for uniform circular targets as a function of size, for various background luminances (foot-lamberts). Redrawn from Blackwell (2).

suggest that there may be duration effects which are operative with increasing times far longer than the classical duration function data would indicate.* Since, however, complete systematic data did not exist which would enable the rigorous conversion of one set of data into terms of the other, it was necessary to devise an expedient set of rules and procedures for making the best possible estimates of the extrapolated, large-target sections of the curves of photopic contrast sensitivity.

This report will present data obtained using target durations of six seconds, and will describe the method used in extending the photopic threshold curves obtained at the Tiffany Foundation to their presumed limiting asymptotes. It is assumed that the reader is familiar with Part I of the report, as the experimental procedures were identical for all adapting luminances and will not be reiterated here, except as certain details were specific to the photopic adaptation case.

Considerable guidance in the construction of the extended curves was gained by recourse to the original record of research of the Tiffany Foundation (3). These raw data, from which the published smoothed data of Blackwell were derived, were consulted in order to evaluate the statistical variability and procedural differences which might bear upon the establishment of rules for performing the extrapolations.

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* Experiments now in progress at the Visibility Laboratory are directed toward quantifying these long-duration effects. First results indicate that the effect is not confined to the high background luminance case.

In this phase of the work very considerable and fundamental help was given by Mrs. Jacqueline I. Gordon and Miss Catharine Fean of the Visibility Laboratory staff.

Apparatus and Procedure

As has already been stated, the experimental arrangements and procedures already described in Part I of this report were essentially similar in the experiments using photopic adapting luminances. The same observers were used, and it should be mentioned that, while the data from the two scotopic levels were reported first, the six adapting luminances were actually presented in random order. For certain of the higher levels, the integrating box was operated by use of lamps within the cavity, rather than by the adjustable tubes described in the earlier report. Figure 2 shows the configuration of the viewing situation. No formal pre-adapting period was used, since it was considered that during the time required for visual photometry of the background screen (approximately 10 minutes) the observers had reached a stable adaptation state.

Experimental Results

The complete experimental results are presented in Table I, which includes data for all adapting luminances from 10^{-5} to 1 foot-lambert. As each threshold value is based upon 600 observations, the data of Table I represent 21,600 trials, excluding *Vexierversuche*. As before,

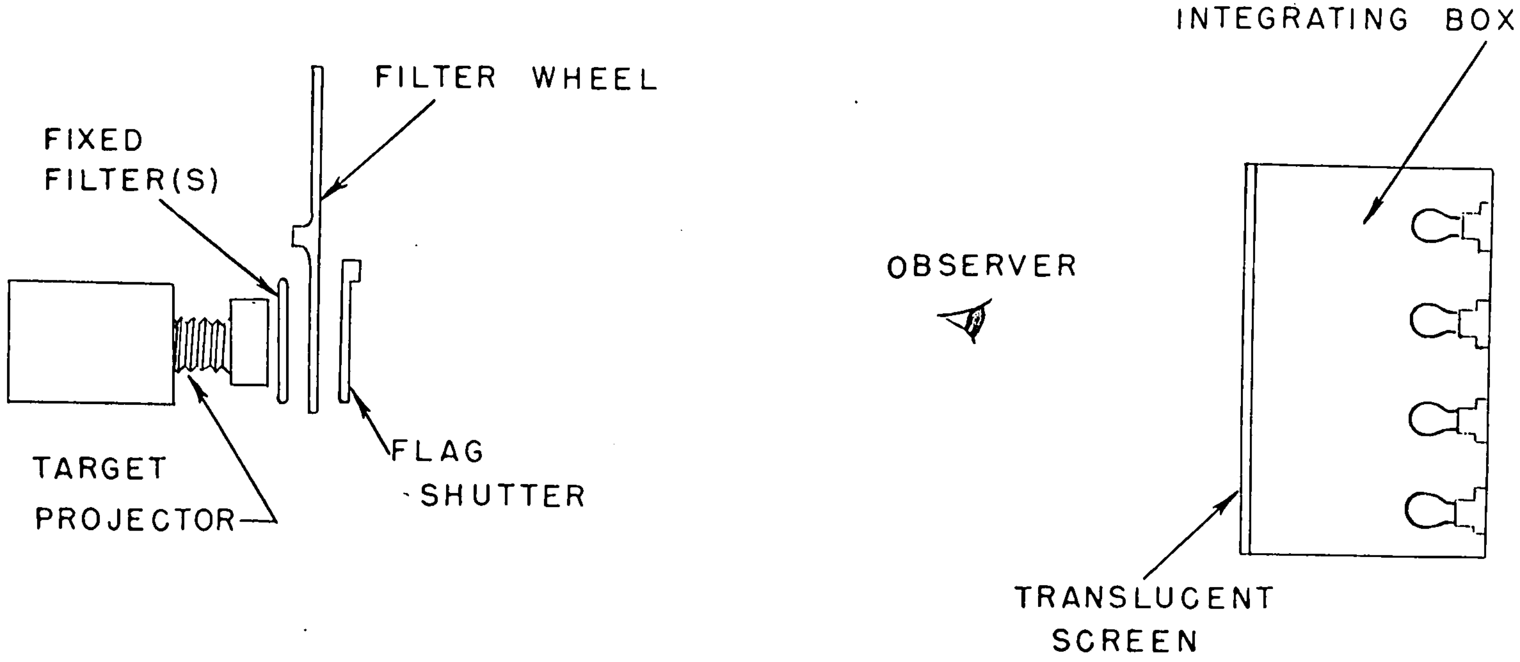

Figure 2. Diagram of the viewing arrangements used, showing integrating box for the production of uniform backgrounds of high luminance.

TABLE I

Observer - R.C.

Target	B_o	C_T	σ_T	b	σ_b	X^2	$P(X^2)$
Split Field	10^{-5}	.0967	.0268	4.375	.461	9.646	.02-.05*
		.0920	.0280	5.628	.849	5.389	.10-.30
		.0932	.0283	5.379	.706	.305	> .90
	10^{-4}	.0552	.0272	5.584	.722	2.262	.50-.70
		.0495	.0262	5.442	.682	6.640	.05-.10
		.0575	.0268	4.904	.578	1.050	.70-.90
	10^{-3}	.0263	.0251	4.527	.663	2.749	.30-.50
		.0202	.0233	6.270	.778	.445	>.90
		.0251	.0263	4.782	.524	.792	.70-.90
	10^{-2}	.00967	.0277	4.396	.498	5.317	.10-.30
		.0117	.0262	4.442	.462	6.825	.05-.10
		.00912	.0275	3.859	.500	8.893	.02-.05*
	10^{-1}	.00934	.0331	3.873	.527	7.461	.05-.10
		.00795	.0258	4.952	.545	1.727	.50-.70
		.00705	.0281	4.129	.458	3.749	.10-.30
	10^{0}	.00536	.0279	4.093	.439	6.616	.05-.10
		.00468	.0258	4.898	.539	3.132	.30-.50
		.00468	.0318	4.148	.584	4.010	.10-.30
6°	10^{-5}	.123	.0233	4.960	.461	5.050	.10-.30
		.153	.0245	4.547	.423	2.371	.50-.70
		.126	.0242	5.907	.742	1.802	.50-.70
	10^{-4}	.0725	.0258	5.227	.605	7.073	.05-.10
		.0620	.0283	3.752	.391	2.796	.30-.50
		.0675	.0211	5.759	.526	5.155	.10-.30
	10^{-3}	.0295	.0276	4.018	.431	8.493	.02-.05*
		.0309	.0267	3.535	.321	2.396	.50-.70
		.0324	.0262	4.082	.389	.256	> .90
	10^{-2}	.0245	.0290	4.058	.438	.201	>.90
		.0282	.0277	5.079	.684	.764	.70-.90
		.0229	.0242	4.320	.388	2.242	.50-.70
	10^{-1}	.0114	.00921	13.262	1.234	6.978	.05-.10
		.0138	.0106	14.115	1.539	1.950	.50-.70
		.0129	.00983	13.287	1.364	.056	>.90
	10^{0}	.00852	.0217	6.320	.656	1.973	.50-.70
		.00902	.0259	3.937	.355	2.601	.30-.50
		.00880	.0258	4.371	.435	10.410	.01-.02*

*$P(X^2)$ <.05 is questionable

TABLE I, continued

Observer - J.F.

Target	B_o	C_T	σ_T	b	σ_b	X^2	$P(X^2)$
Split Field	10^{-5}	.0902	.0216	6.182	.641	.233	> .90
		.105	.0258	5.521	.181	.969	.70-.90
		.100	.0199	6.529	.673	3.635	.30-.50
	10^{-4}	.0479	.0261	5.074	.649	6.210	.10-.30
		.0484	.0220	5.885	.635	4.527	.10-.30
		.0490	.0228	5.082	.476	.258	> .90
	10^{-3}	.0215	.0227	6.612	.912	4.533	.10-.30
		.0195	.0269	6.214	.941	.374	> .90
		.0164	.0215	5.543	.609	1.122	.70-.90
	10^{-2}	.00980	.0289	4.358	.525	3.510	.30-.50
		.00750	.0365	3.018	.399	3.433	.30-.50
		.00795	.0307	3.975	.562	4.533	.10-.30
	10^{-1}	.00322	.0535	2.554	.612	4.425	.10-.30
		.00730	.0254	4.472	.477	.438	> .90
		.00670	.0355	3.004	.383	1.783	.50-.70
	10^{0}	.00394	.0253	5.026	.604	2.447	.30-.50
		.00338	.0230	5.010	.520	.280	> .90
		.00346	.0229	5.735	.690	4.370	.10-.30
6°	10^{-5}	.110	.0262	3.866	.375	3.030	.30-.50
		.126	.0249	5.006	.563	.630	.70-.90
		.124	.0290	4.055	.426	11.866	.001-.01*
	10^{-4}	.0540	.0230	5.510	.566	1.180	.70-.90
		.0530	.0246	4.884	.506	.650	.70-.90
		.0501	.0261	5.652	.488	3.746	.10-.30
	10^{-3}	.0224	.0213	5.664	.645	.456	> .90
		.0244	.0213	5.084	.467	1.255	.70-.90
		.263	.0242	4.227	.386	1.213	.70-.90
	10^{-2}	.0182	.0209	6.405	.669	.570	> .90
		.0229	.0222	6.434	.720	1.460	.50-.70
		.0216	.0256	3.697	.338	3.844	.10-.30
	10^{-1}	.0104	.00917	13.225	1.370	3.081	.30-.50
		.0119	.00890	14.263	1.339	3.010	.30-.50
		.0117	.00998	12.571	1.339	.0526	> .90
	10^{0}	.00708	.0349	3.945	.706	4.971	.10-.30
		.00860	.0228	5.587	.558	2.891	.30-.50
		.00776	.0243	4.905	.478	5.950	.10-.30

*$P(X^2)$ < .05 is questionable

TABLE I, continued

Observer - R.P.

Target	B_o	C_T	σ_T	b	σ_b	X^2	$P(X^2)$
Split Field	10^{-5}	.0850	.0174	9.039	.914	.495	>.90
		.0823	.0199	7.749	.972	.767	.70-.90
		.0890	.0185	8.380	.871	.246	>.90
	10^{-4}	.0485	.0195	8.537	1.040	.137	>.90
		.0514	.0238	5.551	.648	5.480	.10-.30
		.0500	.0231	4.997	.447	2.766	.30-.50
	10^{-3}	.0209	.0192	7.580	.780	1.093	.70-.90
		.0181	.0195	8.154	1.041	.712	.70-.90
		.0204	.0203	6.710	.738	1.720	.50-.70
	10^{-2}	.00725	.0189	6.336	.675	5.602	.10-.30
		.00860	.0216	5.736	.595	1.804	.50-.70
		.00758	.0284	5.433	1.024	4.819	.10-.30
	10^{-1}	.00560	.0209	5.211	.461	1.890	.50-.70
		.00610	.0242	4.013	.347	2.969	.30-.50
		.00670	.0295	4.798	.654	.772	.70-.90
	10^{0}	.00396	.0249	5.288	.637	7.210	.05-.10
		.00282	.0240	5.468	.823	7.430	.05-.10
		.00310	.0308	4.018	.526	14.218	.001-.01*
6°	10^{-5}	.130	.0194	6.777	.679	1.294	.70-.90
		.120	.0199	6.573	.0636	2.166	.50-.70
		.100	.0188	6.787	.680	1.755	.50-.70
	10^{-4}	.0570	.0201	5.992	.500	3.084	.30-.50
		.0639	.0175	6.228	.505	4.708	.10-.30
		.0624	.0189	6.592	.573	.455	>.90
	10^{-3}	.0306	.0215	5.077	.413	4.365	.10-.30
		.0288	.0209	5.639	.496	6.024	.10-.30
		.0325	.0202	6.202	.540	.404	>.90
	10^{-2}	.0204	.0200	6.217	.846	.490	>.90
		.0228	.0183	8.248	.850	.222	>.90
		.0204	.0133	9.922	.881	6.900	.05-.10
	10^{-1}	.00891	.00915	14.123	1.339	14.387	.001-.01*
			.00803	14.632	1.413	11.572	.001-.01*
		.00923	.00791	14.936	1.371	10.084	.01-.02*
	10^{0}	..00676	.0166	6.555	.565	.601	.70-.90
		.00760	.0204	6.918	.719	.490	>.90
		.00645	.0190	7.033	.646	.655	.70-.90

*$P(X^2)$ <.05 is questionable

the following quantities appear in the columns of the table:

C_T - the value of threshold contrast

σ_T - the standard error of the threshold

b - the slope of the psychophysical function

σ_b - the standard error of the slope

X^2 - the value of Chi-square

$p(X^2)$ - the Chi-square probability for 3 degrees of freedom

Comparison of the values obtained for the 6° circular target with the Tiffany data show our thresholds to be significantly higher at all but the two lowest background luminances (10^{-5} and 10^{-4} foot-lamberts). These differences are shown graphically in Figure 3, wherein are plotted threshold contrast estimates from the Visibility Laboratory against the smoothed data from the Tiffany study. Departure from the straight line of unit slope appears to commence at some background luminance between 10^{-4} and 10^{-3} foot-lamberts, although the data points at increased luminances are too sparse to define the relationship except in rough terms.

The threshold differences mentioned above obviously preclude the direct and easy use of the present data for extension of the Tiffany curves. The experimental differences between the two studies were outlined in Part I of this report, and it is to one or another of these dissimilarities that the obtained result may be ascribed. Perhaps the most reasonable assumption is that the differences in target duration are responsible. In the Blackwell experiments, the observers were

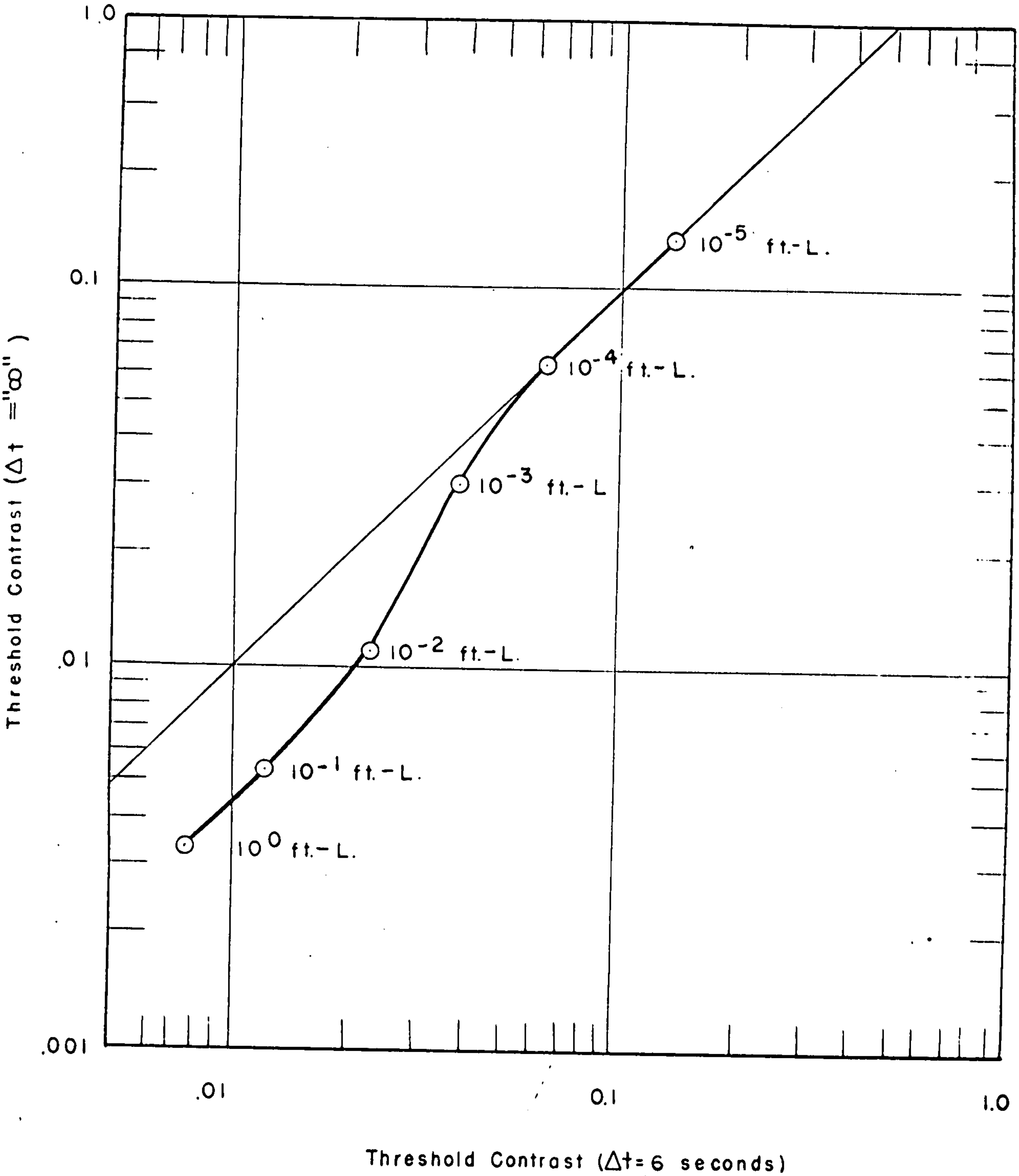

Figure 3

Comparison of threshold contrasts for "infinite" target duration with those for six-second duration. Former data taken from smoothed curves of Blackwell (Tiffany Foundation).

first tested to discover that presentation time which, when doubled would not yield a lower value of threshold contrast.. This was considered the equivalent or "infinite time" and was used for the subsequent collection of data. In the present experiments, however, a uniform target duration of six seconds was used throughout. Another salient difference concerned the use of a somewhat smaller adapting field in our study, owing to the impracticability of arranging the very extensive luminous surround required to duplicate the Tiffany conditions. While either or both of these experimental conditions may contribute to the obtained non-correspondency, the duration function seems to be the more likely cause. In any case, for the purpose of the present application -- the expedient use of the data in visibility problem solving -- it was necessary to estimate the probable curve shapes by appeal to a set of rules and assumptions and to defer the rigorous determination of the complete curves until time and facilities may permit collection of adequate data. The following sections will describe the procedures used in arriving at the curves finally adopted, and from which extended visibility nomographs have been prepared (4).

The Upper Limiting Value of Terminal Contrast

It is possible to set limits for the upper and lower values of contrast at which the Tiffany curves would become asymptotic with increasing target size by making certain assumptions. The upper limits were delineated in terms of the following two assumptions:

(1) That the terminal contrast value must be equal to or lower than the contrast value for the 6° target, and

(2) That the terminal contrast value must be equal to or lower than the Visibility Laboratory contrast value for split field.

The first assumption is, perhaps, trivial, and asserts that the curves for adaptation luminances below 10 foot-lamberts will exhibit the same monotonicity as the Tiffany curves for 10, 100 and 1000 foot-lamberts do. The second assumption implies that an increase in viewing time may lower the contrast threshold, but not raise it. The upper limiting value of contrast is set, accordingly, by the Tiffany 6° thresholds at background luminances 10^{0} and 10^{-1} foot-lamberts, and by the Visibility Laboratory split field data at 10^{-2} and 10^{-3} foot-lamberts.

The Lower Limiting Value of Terminal Contrast

In setting the lower limits for terminal contrast, again two assumptions were made:

(1) That the asymptotic contrast value for any given adaptation luminance must equal or exceed the value for any adaptation luminance greater than itself, and

(2) That the change in contrast threshold between 6° and the asymptote must be equal to or less than the change found using target durations of six seconds.

The first assumption simply states that there will be no anomalous crossing of the curves before reaching a contrast asymptote, and is well supported by our results as well as by the Tiffany data for which an asymptote has been reached. The second assumption, which asserts that the magnitude of the differences between 6^{o} and terminal target sizes is not constant with size but decreases as subtense increases, is based upon the first. If one considers data from the 10^{o} foot-lambert background case, for example, it is clear that if the foregoing were not true, then the terminal contrast would be less than that for 10 foot-lamberts; a violation of the first assumption. The same situation holds at the 10^{-1} foot-lambert level also, and it is believed justifiable to assume that the remaining two levels will exhibit the same property.

Extrapolation of the Tiffany Smooth Data to a Terminal Contrast

Using the foregoing criteria for the establishment of upper and lower limits for the terminal contrast which might be expected to set the contrast asymptote for each of the Blackwell curves, the final extrapolations were made. Table 2 presents a summary of the contrast values obtained with 6^{o} targets at the Tiffany Foundation, the values determined experimentally here for 6^{o} and split-field targets, and the upper and lower limits of terminal contrast adopted for the adaptation luminances for which there was need.

Table II

Adaptation Level (ft-L)	Tiffany Smooth Data		Visibility Lab Data		Limits	
	6°	Terminal	6°	Terminal	Upper	Lower
10^{3}	.00272	.00272			.00272	.00272
10^{2}	.00272	.00272			.00272	.00272
10^{1}	.00277	.00277			.00277	.00277
10^{0}	.00334		.00745	.00383	.00334	.00277
10^{-1}	.00534		.0119	.00577	.00534	.00277
10^{-2}	.0110		.0221	.00883	.00883	.00439
10^{-3}	.0303		.0373	.0218	.0218	.0176
10^{-4}	.0624		.0622	.0509	.0510	.0510
10^{-5}	.136		.132	.0895	.0923	.0923

Construction of the completed curves was undertaken on the basis of the foregoing considerations, and with the further assumption that both terminal contrast and the target size at which the asymptote was reached would be smooth functions of background luminance.

Certain secondary considerations influenced the plotting of some of the individual curves. For example, the curve at 10^{0} foot-lamberts had so nearly reached its asymptote by the time the target had increased to 6°, that it was clear that the terminal contrast must lie very close to the upper limit shown in Table II. In the 10^{-3} foot-lambert case, no such convenient clue presented itself, and the problem of setting some value between the limits arose. It was found that the effect upon sighting range (which is nomographically related to target size in usual visibility problem-solving) in moving from one limit to the other amounted to approximately 15 per cent. Accordingly, the terminal contrast adopted was that midway between the limits, so that the range uncertainty amounts to only ± 7.5 per cent.

The complete family of curves for all adaptation levels is shown in Figure 4. This Figure, it should be emphasized, is not sufficiently accurate as regards curve shape and threshold values to warrant its use for more than gross inspection. In this laboratory, very accurate data plots were made upon large logarithmic graph paper (10 inches per cycle) from which tabular presentation of the data could be made. The values read from these large-scale plots are given in Table III, which forms an extension of the tabulated data to be found in the record of the Tiffany research as published in a Summary Technical Report (5).

It is realized that the data generated in the above manner must be regarded as tentative until further experiments are performed to discover the methodological differences responsible for the apparent failure of the data to correspond at certain adaptation levels.

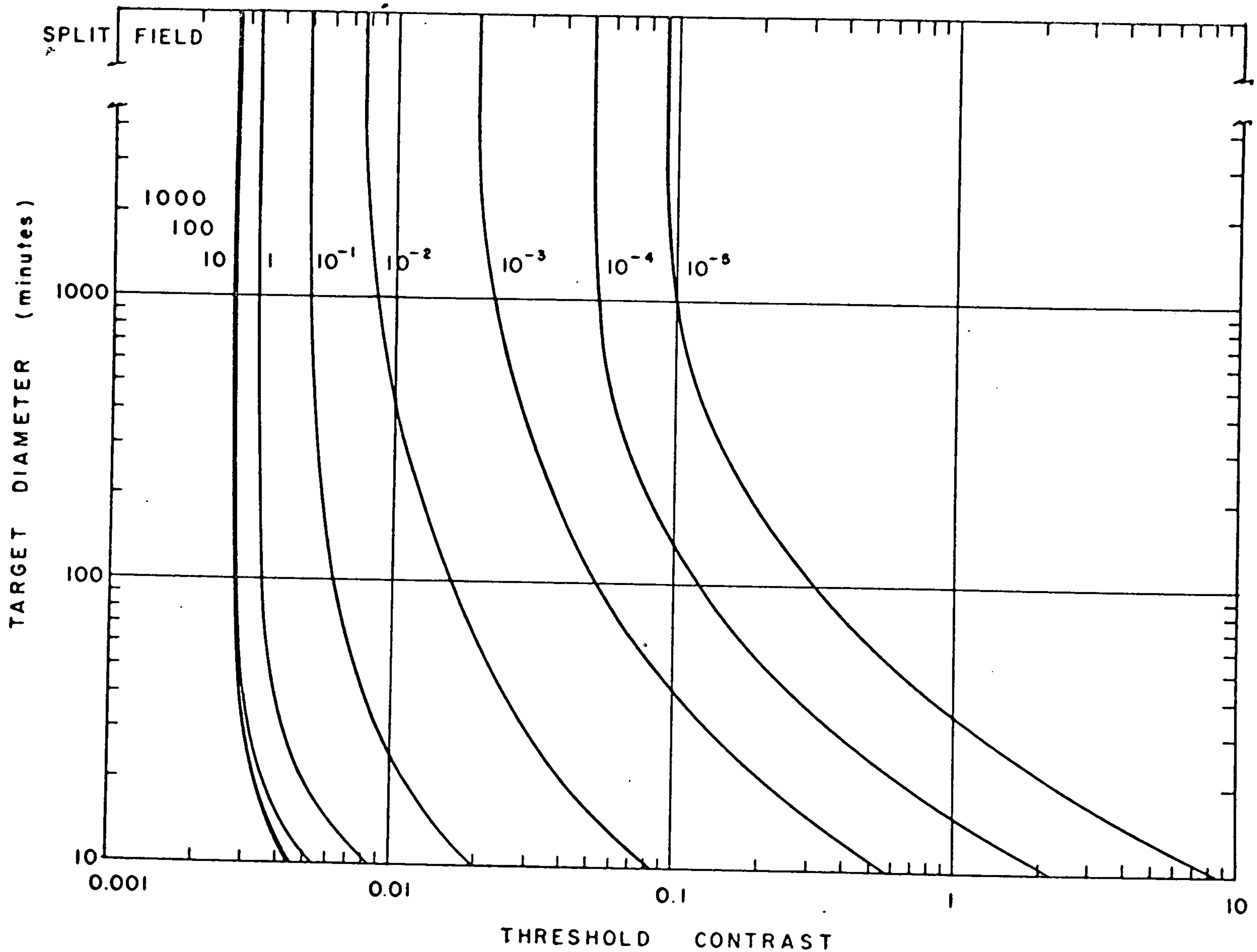

Figure 4

Extended curves of threshold contrast as a function of target size. For explanation see text.

TABLE III

Target Subtense (Min.)		Adaptation Luminance (foot-lamberts) 1000	100	10	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}
360	(6°)	.00272	.00272	.00277	.00334	.00534	.0110	.0302	.0621	.135
370					.00334	.00533	.0109	.0300	.0615	.133
380					.00333	.00532	.0108	.0297	.0610	.131
390					.00333	.00531	.0107	.0294	.0606	.130
400					.00333	.00530	.0106	.0291	.0602	.128
410					.00333	.00529	.0105	.0288	.0598	.127
420	(7°)				.00333	.00528	.0105	.0286	.0594	.126
430					.00333	.00527	.0104	.0284	.0591	.125
440					.00333	.00526	.0103	.0282	.0588	.124
450					.00333	.00525	.0103	.0280	.0586	.123
460					.00333	.00524	.0102	.0278	.0583	.122
470					.00333	.00523	.0102	.0276	.0580	.121
480	(8°)				.00333	.00522	.0101	.0274	.0578	.120
490					.00333	.00521	.0101	.0272	.0575	.119
500					.00332	.00520	.0100	.0270	.0573	.118
510						.00520	.00995	.0269	.0571	.118
520						.00519	.00990	.0268	.0569	.117
530						.00519	.00985	.0266	.0567	.116
540	(9°)					.00518	.00980	.0264	.0565	.116
550						.00518	.00975	.0263	.0564	.115
560						.00517	.00970	.0262	.0563	.114
570						.00517	.00966	.0260	.0562	.114
580						.00516	.00963	.0258	.0561	.113
590						.00516	.00960	.0257	.0560	.113
600	(10°)					.00515	.00956	.0256	.0559	.112
610						.00515	.00953	.0255	.0558	.112
620						.00514	.00950	.0254	.0557	.111
630						.00514	.00946	.0253	.0556	.111
640						.00514	.00943	.0252	.0555	.110
650						.00514	.00940	.0251	.0554	.110
660	(11°)					.00513	.00936	.0250	.0553	.109
670						.00513	.00933	.0249	.0552	.109
680						.00513	.00930	.0248	.0551	.109
690						.00512	.00926	.0247	.0550	.108
700						.00512	.00923	.0246	.0549	.108
710						.00512	.00920	.0245	.0548	.108
720	(12°)					.00511	.00917	.0244	.0547	.107
730						.00511	.00914	.0243	.0546	.107
740						.00511	.00911	.0242	.0545	.107
750						.00511	.00908	.0241	.0544	.107
760						.00510	.00906	.0240	.0543	.106

TABLE III, continued

Target Subtense (Min.)		Adaptation Luminance (foot-lamberts) 1000	100	10	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}
770		.00272	.00272	.00277	.00332	.00510	.00904	.0240	.0542	.106
780	(13°)					.00510	.00902	.0239	.0542	.106
790						.00509	.00900	.0238	.0541	.105
800						.00509	.00898	.0237	.0541	.105
810						.00509	.00896	.0237	.0540	.105
820						.00508	.00894	.0236	.0540	.104
830						.00508	.00892	.0236	.0539	.104
840	(14°)					.00508	.00890	.0235	.0539	.104
850						.00507	.00888	.0234	.0538	.104
860						.00507	.00886	.0233	.0538	.103
870						.00507	.00884	.0233	.0537	.103
880						.00506	.00882	.0232	.0537	.103
890						.00506	.00880	.0231	.0536	.103
900	(15°)					.00506	.00878	.0231	.0536	.102
910						.00505	.00876	.0230	.0535	.102
920						.00505	.00874	.0229	.0535	.102
930						.00505	.00872	.0229	.0534	.102
940						.00505	.00870	.0228	.0534	.102
950						.00504	.00868	.0228	.0533	.101
960	(16°)					.00504	.00866	.0227	.0533	.101
970						.00504	.00864	.0226	.0532	.101
980						.00504	.00863	.0226	.0532	.101
990						.00503	.00862	.0226	.0531	.101
1000						.00503	.00860	.0225	.0530	.101
1050						.00502	.00854	.0222	.0529	.100
1100						.00502	.00848	.0220	.0528	.0990
1150						.00501	.00842	.0218	.0527	.0985
1200	(20°)					.00501	.00837	.0216	.0526	.0980
1250						.00500	.00832	.0214	.0525	.0976
1300						.00499	.00828	.0213	.0524	.0972
1350						.00499	.00824	.0212	.0523	.0968
1400						.00498	.00820	.0210	.0522	.0964
1450						.00498	.00817	.0209	.0521	.0961
1500	(25°)					.00497	.00814	.0208	.0520	.0958
1550						.00497	.00812	.0207	.0519	.0954
1600						.00496	.00810	.0206	.0518	.0951
1650						.00496	.00808	.0205	.0517	.0949
1700						.00496	.00806	.0204	.0517	.0947
1750						.00495	.00804	.0203	.0516	.0946
1800	(30°)						.00802	.0203	.0516	.0944
1850							.00800	.0202	.0515	.0942
1900							.00799	.0201	.0515	.0941

TABLE III, continued

Target Subtense (Min.)	Adaptation Luminance (foot-lamberts) 1000	100	10	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}
1950	.00272	.00272	.00277	.00332	.00495	.00798	.0201	.0514	.0939
2000						.00798	.0200	.0514	.0938
2100 (35°)						.00797	.0199	.0513	.0936
2200						.00797	.0199	.0513	.0934
2300						.00796	.0199	.0512	.0932
2400 (40°)						.00796	.0198	.0512	.0930
2500						.00795	.0198	.0511	.0928
2600							.0198	.0510	.0926
2700 (45°)							.0198	.0510	.0924
2800							.0198	.0510	.0923
2900							.0198	.0510	.0922
3000 (50°)							.0197	.0510	.0921
3100								.0509	.0920
3200								.0509	.0919
3300 (55°)									.0918
3400									
3500									
3600 (60°)									
3700									

Acknowledgement

The preparation of the extrapolated curves which are the primary concern of this report has been greatly assisted by the efforts of other members of the staff of the Visibility Laboratory. Grateful acknowledgement is made to Mrs. Jacqueline Gordon, Miss Catharine Fean, Dr. S.Q. Duntley, and Mr. James Harris for their help and suggestions. Thanks are due also to Mr. Robert Colsky, Mr. John Foster, and Mr. Robert Puich who have served as observers during the rather extensive period required for data collection.

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