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STUDIES OF DISPLAY SYMBOL LEGIBILITY

Part XVI: The Legibility of Teletypewriter Symbols on Television

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APRIL 1967

G. L. Bell

Prepared for
COMMAND SYSTEMS
COMPUTER AND DISPLAY DIVISION
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 512C

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FOREWORD

This report is one of a series describing symbol legibility for television display. Additional information on this topic may be found in the following reports: "Studies of Display Symbol Legibility: The Effects of Line Construction, Exposure Time, and Stroke Width," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-249, February 1963; "Studies of Display Symbol Legibility, II: The Effects of the Ratio of Width of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-440, July 1963; "Studies of Display Symbol Legibility, III: Line Scan Orientation Effects," by B. Botha, D. Shurtleff, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-138, May 1966; "Studies of Display Symbol Legibility, IV: The Effects of Brightness, Letter Spacing, Symbol Background Relation, and Surround Brightness on the Legibility of Capitol Letters," by D. Shurtleff, B. Botha, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-134, May 1966; "Studies of Display Symbol Legibility, V: The Effects of Television Transmission on the Legibility of the Common Five-Letter Words," by G. Kosmider, The MITRE Corp., Bedford, Mass., ESD-TR-65-135, May 1966; "Studies of Display Symbol Legibility, VI: Leroy and Courtney Symbols," by D. Shurtleff, and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-136, May 1966; "Studies of Display Symbol Legibility, VII: Comparison of Displays at 945- and 525-Line Resolutions," by D. Shurtleff and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-137, May 1966; "Studies of Display Symbol Legibility, VIII: Legibility of Common Five-Letter Words," by G. Kosmider, M. Young, and G. Kinney, The MITRE Corp., Bedford, Mass., ESD-TR-65-385, May 1966; "Studies of Display Symbol Legibility, IX: The Effects of Resolution, Size and Viewing Angle of Legibility," by D. Shurtleff, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-65-411, May 1966; "Studies of Display Symbol Legibility, X: The Relative Legibility of Leroy and Lincoln/MITRE Alphanumeric Symbols," by D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-115, August 1966; "Studies of Display Symbol Legibility, XI: The Relative Legibility of Selected Alphanumerics in Two Fonts," by G. Kinney and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-116, August 1966; "Studies of Display Legibility, XII: The Legibility of Alphanumeric Symbols for Digitalized Television," by G. Kinney, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-117, August 1966; "Studies of Display Symbol Legibility, XIII: Studies of the Legibility of Alphanumeric Symbols in the BUIC Symbol," by G. Kinney and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-302, August 1966; and "Studies in Display

FOREWORD (Concluded)

Symbol Legibility, XIV: The Legibility of Military Map Symbols on Television," by M. Marsetta and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-66-315, September 1966; and "Studies of Display Legibility, XV: Realtive Legibility of Leroy and Teletypewriter Symbols," by G. L. Bell, The MITRE Corp., Bedford, Mass., ESD-TR-66-316, September 1966.

ABSTRACT

The legibility of Long Gothic and Murray teletype symbol fonts was studied on television. Subjects identified light symbols on a dark background at four resolutions. The results showed that three special cloud-cover symbols were illegible for all resolutions studied. Under ideal conditions, 10 active lines per symbol height was the minimum recommended resolution for the alphanumeric symbols. The Long Gothic and Murray symbols were equally legible. It is recommended that more legible symbols be used for the three cloud-cover conditions.

REVIEW AND APPROVAL

This technical report has been reviewed and is approved.

CHARLES A. LAUSTRUP, Colonel, USAF
Chief, Computer and Display Division

ACKNOWLEDGMENTS

The writer is indebted to Miss Lyne Smith, who ran the subjects, and Mr. Gilbert Monty who set up and maintained the equipment for this study.

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SECTION I

INTRODUCTION AND BACKGROUND

One of the printed materials that is read and processed by operators in air defense and air traffic control systems is a teletyped weather report. The most frequently occurring report is the Hourly Sequence Report (HSR) which is typed on yellow paper in standard codes and formats. The type symbols are of two styles (or fonts), Long Gothic and Murray (Figures 1 and 2). Military teletype printers have type pallets of the Long Gothic style for the alphanumeric symbols, plus five type pallets (the metal part that strikes the ribbon) of the Murray style for zero and the cloud-cover symbols ○, ⦶, ⦷, and ⊕ (called clear, scattered, broken and overcast). This combination of the two type styles is called the Long Gothic font in this paper. Civilian teletype printers have Murray pallets for all symbols. The legibility of these symbols is of interest especially to designers of display systems who contemplate using a closed-circuit television system to distribute the HSR to several viewers. This paper reports a study comparing Long Gothic and Murray on television.

Two experiments on the legibility of both fonts were reported earlier.[1] One experiment was a controlled-exposure-time test which showed the symbols one-at-a-time randomly with respect to alphabetical and numerical order. The Long Gothic and Murray fonts were compared with a standard

A B C D E F G H I K L M N P Q R S T

U V W X Y Z 1 2 3 4 5 6 7 8 9

Figure 1. Long Gothic Symbols

A B C D E F G H I K L M N P Q R S T

U V W X Y Z 1 2 3 4 5 6 7 8 9 Ø ⦶ ⦷ O ⊕

Figure 2. Murray Symbols

Leroy font of the same stroke-width, and each symbol occurred five times. Of course, in an HSR some symbols are used more often than others and there is a fixed format. Therefore, in the second experiment, the symbols were shown with the relative frequencies occurring in a typical HSR, the effects of format being left for a later study. It was found in these experiments with solid-stroke symbols that the unequal frequencies of symbol occurrence improved the subjects' performances, but that the two HSR fonts were not as legible as the Leroy font. The present study repeats the first of these two experiments, but with the symbols shown on a television monitor at various resolutions. The Leroy font was not included since other studies have been made on the legibility of televised Leroy symbols.[5,6]

The present study was done with the same "ideal" symbols as in the earlier tachistoscope study, except that each symbol was picked up by a television camera and shown on a monitor. Each symbol seen by the camera had sharply defined edges, and all the symbols had a uniform height and stroke-width. The subjects saw the symbols on the monitor at resolutions of 12, 10, 8, and 6 active television lines for the symbol's height, using the Z as the reference symbol for different resolutions.

No differences were found between the Long Gothic and Murray fonts; as resolution decreased, the decrease in legibility was about the same for both fonts. The minimum acceptable resolution for Long Gothic and

Murray alphanumeric symbols under ideal conditions is approximately 10 lines per symbol height. These results have been found in several experiments with alphanumeric symbols in other fonts.[2,3,4,5,6]

An interesting result was the consistently long response times and high number of errors made with the cloud-cover symbols ⦶, ⦷, and ⊕. Even at the best resolution tested, where the alphanumeric symbols had a low number of errors, these three cloud-cover symbols gave too many errors for use on television.

Recommendations are to design and test new cloud-cover symbols, and to produce all Long Gothic and Murray alphanumeric symbols on television with 10 or more lines per symbol height.

SECTION II

APPARATUS

GENERAL DESCRIPTION

The camera of a 945-line closed-circuit television system was focused on a bright symbol projected from a 35 mm film strip onto a translucent screen in a modified Motion Analyzer. The subject saw the symbol on a television monitor. Since the size of the symbol on the translucent screen was fixed, and the raster on the monitor was also fixed, the resolution of the symbol on the monitor was controlled by adjusting the distance between the camera and the translucent screen.

The dimmer control for the overhead lights in the laboratory was marked so that the ambient lighting in the room would be the same throughout the experiment. With the control in this position, a Spectra Brightness Spot Meter read approximately 0.8 fL when focused on a grey cardboard mask on the monitor implosion screen; the mask formed the visual surround, and is discussed later.

The experimenter had a manual switch connected to a stepping switch on the Motion Analyzer and to the reset of a Standard Electric Timer. The stepping switch could be set to advance the film strip by one, two, or up to ten frames each time the manual switch was depressed.

The subject had a manual switch and a microphone which were connected, respectively, to the electric timer and to a relay in the video signal input to the monitor (see Figure 3). When the subject depressed

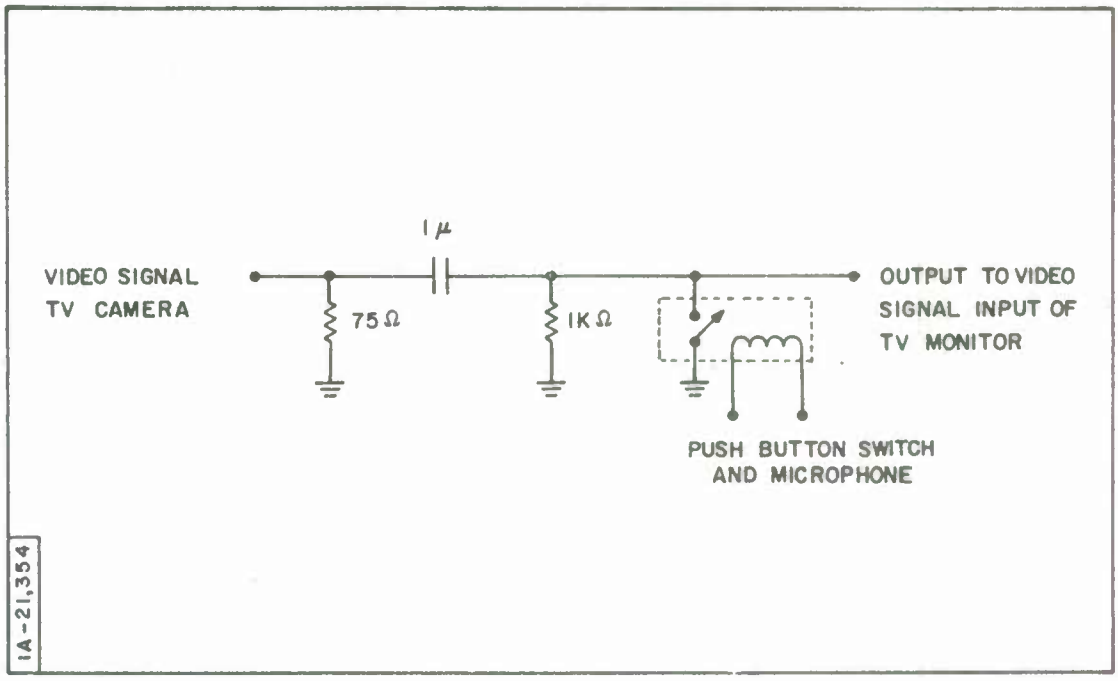

Figure 3. Relay Switch in Video Signal Input to TV Monitor

the switch, the clock started and the symbol appeared on the monitor. When the subject spoke into the microphone, the clock stopped and the symbol disappeared. Response time was recorded to the nearest 0.01 second.

SYMBOLS

The film strips were those used for the first study with the tachistoscope.[1] Scale drawings of the symbols on the type pallets of the teletypewriters were photographed on 35 mm DuPont Cronar-Ortho A Litho film so that one symbol appeared in each frame.

One film strip had all Murray symbols and the other had the combination of Long Gothic alphanumeric with Murray "zero" and four cloud-cover symbols. The symbols on the film strips were those appearing in the weather section of the Hourly Sequence Reports; these are the letters of the alphabet except J and O, all of the numerals including zero, and the four cloud-cover symbols ○, ⦶, ⦷, and ⊕. In each film strip, each symbol appeared five times making a total of 190 frames per strip. The symbols on the strips occurred randomly with respect to alphabetical or numerical order.

945-Line Television System

The camera was a GPL Precision 820 with an RCA 8507 vidicon tube and a 25 mm Cosmicar television lens (#16140). One Conrac model CQE-14 monitor was mounted over the camera control unit to assist in adjusting the controls. A similar monitor was the one the subject saw. The camera and monitors were set up according to the Operation and Maintenance Manual for Precision 820 Television System. The horizontal and vertical oscillators were synchronized to stabilize the raster on the monitor and provide a better control over the interlace.

A grey cardboard mask was mounted on the implosion screen of the subject's monitor. The mask had a rectangular hole (6/8 inch x 7/8 inch) centered about the position on the monitor screen where the symbol appeared. The subject's monitor was mounted on a table and the subject sat at the table leaning his forehead against a headrest. The symbols appeared on the monitor at the subject's eye-level as he looked straight ahead. The height of the Z subtended an angle of approximately sixteen minutes of arc at the subject's eyes for all resolutions. The distance between the monitor screen and the headrest was adjusted to keep the visual angle constant for different symbol resolutions. Figure 4 shows photographs of some Long Gothic symbols on the television screen.

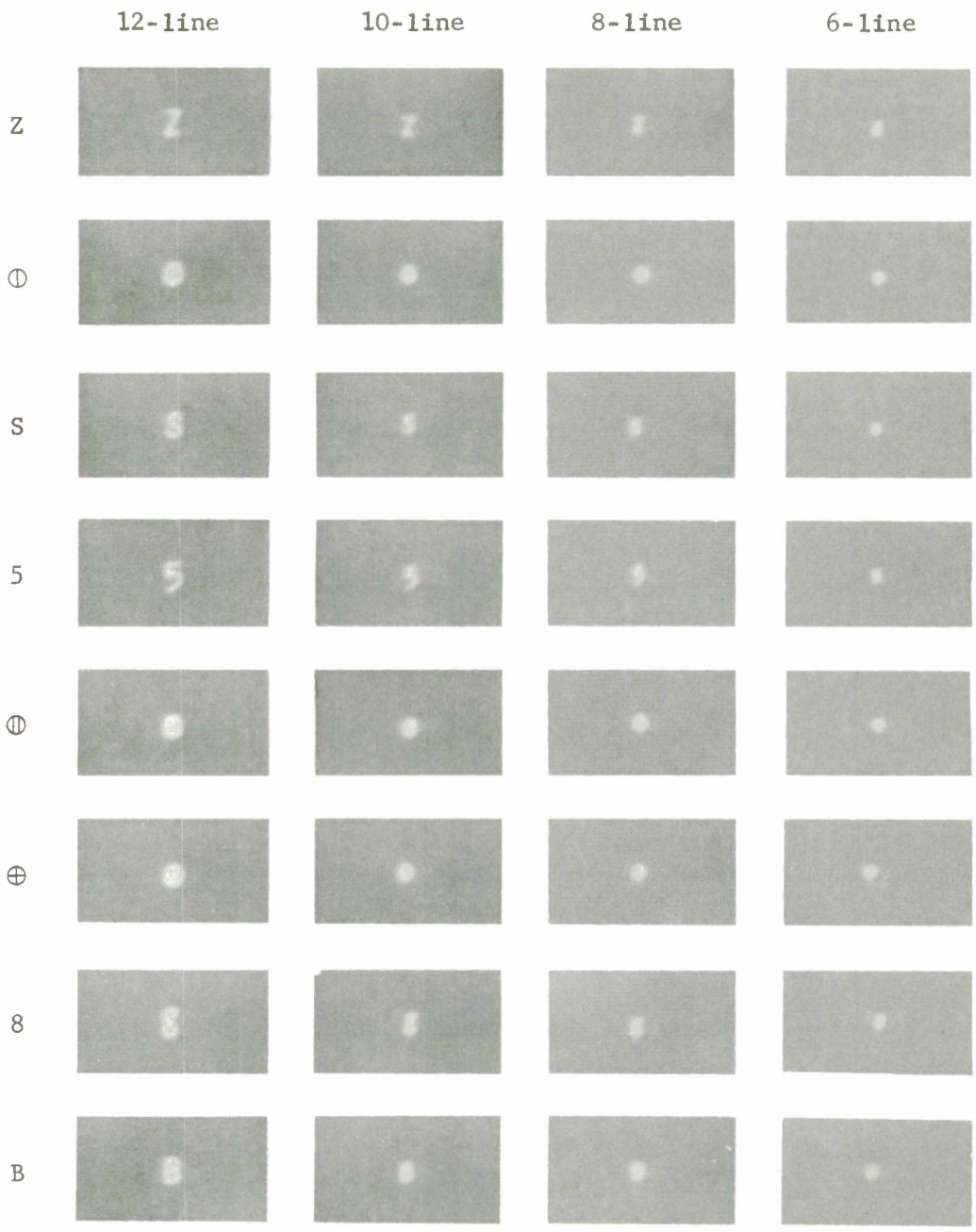

Figure 4. Long Gothic symbols shown at television resolutions of 12, 10, 8, and 6 active lines per symbol height.

Adjusting the Apparatus

At the beginning of each day, the television equipment was adjusted for "best" picture quality after a warm-up period of two hours (see "Operating Procedures" in the Manual). This required a subjective judgment which was made by the same person each day with a television resolution chart.

To set up the rest of the apparatus for each session, the grey cardboard mask was removed from the monitor and the camera was positioned on the correct floor mark for the number of lines per symbol height for the session. With the overhead fluorescent lights in the laboratory turned fully on, the aperture of the camera was set wide open at f1.9, and the lens focused. The overhead lights were dimmed and the letter Z of the font being tested was projected onto the translucent screen. The vertical hold control on the front of the subject's monitor was adjusted until there was no twinning of the lines. (The light and dark lines of the television raster were equally spaced, i.e., not paired.) The number of active lines in the height of the Z on the subject's monitor were counted through a microscope, and any blooming was removed by adjusting the aperture of the camera lens.

The next step was to set the brightness and contrast of the symbols and the background. The experimenter removed the film strip from the Motion Analyzer, leaving a bright patch (1 inch x 3/4 inch) on the

translucent screen. A Spectra Brightness Spot Meter was focused on the patch on the subject's monitor, with the patch always about the same size relative to the reticule of the Spot Meter, with at least 8 active lines in the reticule at the 6-line resolution. This was achieved by changing the power of the lens on the Spot Meter. For the background brightness, the Spot Meter was moved vertically until the top of the bright patch appeared in the lowest part of the field of view. With the contrast and brightness controls on the subject's monitor, the patch brightness was set to 60 fL and the background was set to 3 fL. No variations from these values were observable on the Spot Meter throughout the experiment. The distance between the monitor screen and the subject's headrest was set, the cardboard mask was replaced on the monitor, and the film strip was replaced in the Motion Analyzer.

SECTION III

EXPERIMENTAL PROCEDURE

The subjects were the same three subjects that took part in the experiments with the tachistoscope described earlier.[1] Their vision was tested on a Bausch and Lomb Ortho-Rater and found normal.

A photographic print of the symbols to be seen was given to the subject who was told to speak into the microphone as quickly as possible after identifying each symbol, since both the reaction time and the symbol called would be recorded by the experimenter for each symbol shown. The subject was told that J and O would not appear and that he must make his identification from those symbols on the print, naming one symbol for each symbol shown. He was told that the symbols would occur with equal frequency.

The same sequence of operations was followed for each symbol shown. The experimenter pressed the switch to advance the film strip and reset the clock to zero. The noise of the clock resetting was a signal to the subject that he could see the symbol when ready. The subject then depressed the switch so that the picture appeared on the screen and the timer started. The subject spoke his identification of the symbol into the microphone. The timer recorded, in hundredths of a second, the time taken by the subject to identify each symbol and the experimenter noted this time together with the symbol named and the symbol shown.

A rest of about one minute was given after 45 symbols were shown so that each session was divided into four parts. No subject ran more than two experimental sessions in one day and when two sessions were run in a day, one would be given in the morning and the other in mid-afternoon.

Before the experiment began, each subject was familiarized with all of the symbols on both film strips with the camera placed close to the translucent screen so that the symbols on the monitor were large. The subjects also practiced with all of the symbols at least once for all four resolutions (12, 10, 8, and 6 lines per symbol height) before the data reported in this paper were collected. The four resolutions and fonts were given in a random sequence to each subject.

Before the results were analyzed, the subject's response times were adjusted for the time delay between the timer's starting and the appearance of the symbol on the monitor. The delay was measured by disconnecting the microphone from the clock and the relay switch, and replacing it with a photomultiplier lined up with the symbol on the monitor. The photomultiplier was thus equivalent to a subject with a negligibly small response time. Ten readings were taken, giving an average time delay of 0.08 seconds with a standard deviation of 0.014 seconds.

SECTION IV

RESULTS AND CONCLUSIONS

The mean response times and the numbers of errors are given in Tables 1 and 2 for each subject and both fonts. The mean response times for the symbols of 6-line height are all longer than the times for the 8-line symbols, which are all longer than the times for the 10-line symbols, which are all longer than the times for the 12-line symbols. This result is statistically significant by inspection, indicating that the time needed to identify the symbols increased as the resolution decreased. There was not such a clear separation for the numbers of errors made at the four resolutions except for the 6-line symbol resolution, although in general the numbers of errors increased as the resolution decreased.

The subjects reported that it was very difficult, if not impossible, to distinguish among symbols at 6 lines, and that the cloud-cover symbols ⦶, ⦷, and ⊕ were particularly indistinguishable. It appears from the curves for Set A in Figure 6, which show abnormally low reaction times at 6 lines, that the subjects may have simply named whatever symbol came to mind when the one shown was very illegible instead of delaying for a short interval in the hope of correctly identifying it. One subject reported doing this at 6 lines, and his data show abnormally distorted frequencies of response for particular

Table I

Mean Response Times (in seconds) for 190 Symbols Shown at Four Television Resolutions to Three Subjects

	Long Gothic Font TV Resolution (Number of active lines per symbol height)			
	6	8	10	12
S_1	3.70	1.19	0.79	0.59
S_2	1.70	1.37	0.85	0.54
S_3	1.89	0.96	0.76	0.63

	Murray Font TV Resolution (Number of active lines per symbol height)			
	6	8	10	12
S_1	3.21	1.44	0.69	0.57
S_2	2.19	1.15	0.70	0.46
S_3	1.82	0.93	0.61	0.56

Table II

Numbers of Errors for 190 Symbols Shown at Four Television Resolutions to Three Subjects

	Long Gothic Font TV Resolution (Number of active lines per symbol height)			
	6	8	10	12
S_1	95	21	13	4
S_2	115	20	2	6
S_3	41	8	4	2

	Murray Font TV Resolution (Number of active lines per symbol height)			
	6	8	10	12
S_1	115	29	3	4
S_2	132	19	3	2
S_3	52	8	2	Ø

symbols. (This behavior is called "guessing" from here on; a more elegant treatment of guessing behavior is not attempted because "guessing" occurs under viewing conditions too poor for display use, and therefore is of relatively little interest.) Apparently, 6 lines is such poor resolution that the results at this resolution are not worth detailed analysis, and the relation between resolution and legibility is shown more clearly by the other three resolutions.

> Conclusion 1. Reading performance deteriorates as the resolution of the symbols is decreased from 12 active television lines per symbol height.

To show the types of errors made, confusion matrices were plotted for the combined results of the three subjects (Tables 3 through 10). In a confusion matrix, the symbols which were incorrectly identified are plotted against the symbols shown. Correctly identified symbols are not plotted. Tables 3 through 10 show that the symbols ⦶, ⦷, and ⊕ were involved in a large proportion of the confusions. It was noticed earlier that the response times for these three symbols was about twice that for other symbols. It appeared that these three symbols are so different from all the other symbols, that the data should be treated in separate groups.

Table III

Long Gothic at 12 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	O	⦶	⦷	⊕	Σ
A																																							
B																																							
C																																							
D																																							
E																																							
F																																							
G			2																																				2
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K																																							
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O																																							
⦶																																							
⦷																																				5		3	8
⊕																																				1			1
			2																						1											6		3	12

$\frac{12}{570}$ (2% Error)

Table IV

Murray at 12 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	O	Φ	Θ	⊕	Σ
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Θ																																				3		2	5
⊕																																							
																									1											3		2	6

$\frac{6}{570}$ (1% Error)

Table V

Long Gothic at 10 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	○	⦶	⦷	⊕	Σ
A																																							
B																																							
C																																							
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⦶																																					1	2	3
⦷																																						3	3
⊕																																					3		3
			3									1	1							1					1	1								2			4	5	19

$\frac{19}{570}$ (3% Error)

Table VI

Murray at 10 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	○	⦶	⦷	⊕	Σ
A																																							
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7																																							
8																																							
9																																							
Ø																																							
○																																							
⦶																																							
⦷																																				4		2	6
⊕																																							
									2																											4	2	8

$\frac{8}{570}$ (1% Error)

Table VII

Long Gothic at 8 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	O	⦶	⦷	⊕	Σ
A																																							
B																					1																		1
C																																							
D																																							
E			1																																				1
F																																							
G																														1									1
H												2	1																										3
I																									2														2
K																																							
L																																							
M																												1											1
N								1																															1
P																																							
Q																																							
R																																							
S																																2		1					3
T																									1														1
U																																							
V																																							
W																7																		3					10
X																																							
Y																																							
Z																										4													4
1									2																														2
2																																							
3																																							
4																																							
5																																							
6																																							
7																																							
8																																							
9																																							
Ø																																			1	1			2
O																																							
⦶																																				1	4		5
⦷																																			2		6		8
⊕																																			3	1			4
Σ			1					1	2			2	1			7					1				3	4		1		1		2		4	6	3	10		49

$\frac{49}{570}$ (9% Error)

Table VIII

Murray at 8 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	○	◐	◑	⊕	Σ
A																																							
B				2													1																						3
C																																							
D																																							
E																																							
F																																							
G															1																					1			2
H												1										1																	2
I																									2														2
K																						3																	3
L																																							
M								4					1																										5
N										1							2				1																		4
P																																							
Q							1																																1
R																																1							1
S																																1							1
T																							2								2								4
U								1																															1
V																																							
W												5																											5
X																																							
Y																				1																			1
Z																																							
1																																							
2																																							
3																																							
4																																							
5																																							
6																																							
7																																							
8		1										1					2																						4
9																																							
Ø																																				2			2
○																																							
◐																																				6			6
◑																																			1			6	7
⊕																																				2			2
Σ	1			2			1	5		1		7	1		1		5			1	1	4	2		2						2	2			2	10	6		56

$\frac{56}{570}$ (10% Error)

Table IX

Long Gothic at 6 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	O	Ⓘ	Ⓘ	⊕	Σ
A																												6											6
B				2																								1										5	8
C					3			1																1															5
D		3					1										1												1							1		4	11
E			1				1								1					1				1						1									6
F																				1																			1
G																												4		2									6
H												3									3	1																4	11
I																				1					4														5
K													1			1					3	2						2										1	10
L																																							
M								1													5																	5	11
N				1																	1							2										5	9
P						3																																	3
Q		1					3										2											3									2	3	14
R		1		1				1													1	1				1												5	11
S					1																								1	1		2						2	7
T						1			2														1		1														5
U				2								2	1								2							2										3	12
V																							1															1	2
W		1						1				1				2																		1			1	6	13
X								1					1				1				1																	3	7
Y									1											3											2								6
Z																										4													4
1									3											2																			5
2																											1	1			1	1							4
3																													1										1
4		2																																				1	3
5																																	1						1
6																																							
7																											1												1
8		1			3											1				1				2															8
9																																							
Ø				1	1			1					1								2																	5	11
O		1		1																																2	1	6	11
Ⓘ				1																																		13	14
Ⓘ																																						13	13
⊕																																				1	5		6
	10	1	9	8	4	5	6	6				6	4		1	4	4			9	18	4	2	4	5	5	2	21	3	4	3	3	1	1		4	9	85	251

$\frac{251}{570}$ (44% Error)

Table X

Murray at 6 Lines per Symbol Height

Symbol Called

Symbol Shown	A	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	Ø	○	◐	◑	⊕	Σ
A																												1											1
B				1									3															2					1					3	10
C					2		2																					3							2			1	10
D		2																											4			1						1	8
E	1	2					1				1						1							1															7
F														2				1																					3
G																												3	1			1		1		1	2	2	11
H	2									1		1	3								5	2																	14
I																									4														4
K													1			1	1				3	4					2	1						1					1	15
L	1																								2			1											4
M								1					1								6													1				1	10
N																3					3											1					2	4	13
P						3														1																		1	5
Q							1						2															6		1						1	1	12
R	1											2	2								3					1		1	1					1					12
S		2			1																2						1	3					1	1				2	13
T									1											1											3								5
U												1	1								6	1														1	1	1	12
V						1															2																		3
W												3																											3
X	1							1					1								2								1										6
Y						2												1		5																			8
Z	1							2	2																	1		1											7
1									6																														6
2	2																											1										1	4
3									4																			1	1										6
4																																							
5																																	10						10
6																												9								1			10
7									2									4																					6
8													2	1							1							2						1			1	1	9
9		2															1											1	2								1	1	8
Ø						1							1	2							1															1	4	10
○																																		1		4		1	6
◐		1																																			2	12	15
◑		1																														1				1		9	12
⊕																																					1		1
Σ	9	10		1	3	7	4	4	15	1	1	7	17	5		4	3	6		7	34	7		1	6	2	3	36	10	1	3	4	12	7	2	8	12	47	299

$\frac{299}{570}$ (52% Error)

The results were regrouped, and the symbols ⦶, ⦷, and ⊕ are called set A and the ○ and alphanumeric symbols are set B. Tables 11 through 14 give the mean response times and numbers of errors for each subject for the two symbol sets in both fonts. In the following discussion, set A is compared with set B.

The percentage of errors in set A was greater than the percentage of errors in set B at all four resolutions. For both fonts the percentage of errors for set A at the 12-line resolution was greater than the percentage of errors for set B at the 8-line resolution. For the mean response times, only at the 6-line resolution were the times for set A less than those for set B. At the 12-line resolution, the mean response times for set A were about twice those for set B. Set A was inferior to set B on television, as judged by reading performance.

> Conclusion 2. The symbols ⦶, ⦷, and ⊕ are less legible than the alphanumeric symbols of the Murray and Long Gothic fonts on television.

The results for symbol set A, that is, the symbols ⦶, ⦷, and ⊕, show that the percentages of errors were about the same at the 12-line and 10-line resolutions, but increased sharply below the 10-line resolution. Although the mean response times increased from the 12-line to the 10-line resolution, the times were more variable between subjects

Table XI

Numbers of Errors for 15 Symbols of Set A and 175 Symbols of Set B in the Long Gothic Font, Shown at Four Television Resolutions to Three Subjects

		Long Gothic Font TV Resolution (Number of active lines per symbol height)			
		6	8	10	12
Symbol Set A ⦶ ⦷ ⊕	S_1	11	10	6	3
	S_2	10	4	1	5
	S_3	12	3	2	1
	Σ	33	17	9	9
	Mean Error	11.0	5.7	3.0	3.0
	Percent Error	73%	38%	20%	20%
Symbol Set B ○ and alphanumerics	S_1	84	11	7	1
	S_2	105	16	1	1
	S_3	29	5	2	1
	Σ	218	32	10	3
	Mean Error	72.7	10.7	3.3	1.0
	Percent Error	41%	6%	2%	1%

Table XII

Numbers of Errors for 15 Symbols of Set A and 175 Symbols of Set B in the Murray Font, Shown at Four Television Resolutions to Three Subjects

		Murray Font TV Resolution (Number of active lines per symbol height)			
		6	8	10	12
Symbol Set A ⦶ ⦷ ⊕	S_1	10	8	3	3
	S_2	10	5	2	2
	S_3	8	2	1	Ø
	Σ	28	15	6	5
Mean Error		9.3	5.0	2.0	1.7
Percent Error		62%	33%	13%	11%
Symbol Set B ○ and alphanumerics	S_1	105	21	Ø	1
	S_2	122	14	1	Ø
	S_3	44	6	1	Ø
	Σ	271	41	2	1
Mean Error		90.3	13.7	0.7	0.3
Percent Error		52%	8%	0%	0%

Table XIII

Mean Response Times (in seconds) for 15 Symbols of Set A and 175 Symbols of Set B in the Long Gothic Font, Shown at Four Television Resolutions to Three Subjects

		Long Gothic Font TV Resolution (Number of active lines per symbol height)			
		6	8	10	12
Symbol Set A ⦶ ⦷ ⊕	S_1	2.66	1.51	1.94	1.49
	S_2	0.86	1.61	1.95	1.06
	S_3	2.86	1.64	1.72	1.37
	Mean	2.13	1.59	1.87	1.31
Symbol Set B ○ and alphanumerics	S_1	3.79	1.16	0.69	0.51
	S_2	1.77	1.35	0.75	0.49
	S_3	1.81	0.91	0.68	0.56
	Mean	2.46	1.14	0.71	0.52

Table XIV

Mean Response Times (in seconds) for 15 Symbols of Set A and 175 Symbols of Set B in the Murray Font, Shown At Four Television Resolutions to Three Subjects

		Murray Font TV Resolution (Number of active lines per symbol height)			
		6	8	10	12
Symbol Set A ⦶ ⦷ ⊕	S_1	1.99	1.98	1.47	1.08
	S_2	1.17	2.12	1.40	0.68
	S_3	2.07	1.72	1.26	1.04
	Mean	1.74	1.94	1.38	0.93
Symbol Set B ○ and alphanumerics	S_1	3.31	1.39	0.62	0.53
	S_2	2.27	1.07	0.63	0.44
	S_3	1.80	0.86	0.55	0.51
	Mean	2.46	1.11	0.60	0.49

for the 8-line and the 6-line resolutions. Together with the sharp increase in numbers of errors, particularly at the 6-line resolution, this again indicates that the subjects were largely guessing at the 6-line resolution. Notice that at the best resolution tested (12 lines) the percentage of errors for symbol set A would be too high for display use. A previous study[1] with ideal, solid-stroke symbols showed that these symbols are not acceptably legible, from which it follows that resolutions greater than 12 lines would not be sufficient to make them acceptably legible on television.

> Conclusion 3. The symbols ⦶, ⦷, and ⊕ are not sufficiently legible for use on television.

Recommendations for these three symbols will be discussed later.

Symbol set B contains the clear cloud-cover symbol ○ and the alphanumeric symbols. In both fonts, the percentage of errors was about the same for the 12-line and 10-line resolutions. There was an increase in the percentage of errors as the resolution decreased to 8 lines and a large increase in errors at 6 lines. Again, this indicates that the subjects were largely guessing at the 6-line resolution. No statistical tests were made on these results because the errors at 6 lines appear to be based on guesses and the numbers of errors at 10 and 12 lines are too small to permit analysis. In each font, there was no overlap between

the response times given at one resolution and the times given for another resolution for all three subjects (see Tables 13 and 14). This is a statistically significant result by inspection and indicates the decrease in reading performance with decreasing resolution.

> Conclusion 4. For Long Gothic and Murray alphanumeric symbols, reading performance deteriorates as the television resolution decreases from 12 lines per symbol height.

Tables 11 and 12 show that, for set B, the 6-line and 8-line symbols had enough errors to cause some doubts about using either font in a display. The errors at 10 and 12 lines were so few that no problem is seen at these resolutions.

The results in Tables 11 through 14 may be easier to interpret in graphical form. Figures 5 and 6 show the percentage of errors and mean response times for the combined results of the three subjects at the four resolutions for the Long Gothic and Murray fonts. All of the curves for set B steepen below 10 lines per symbol height. These results indicate that the subjects' performances with set B deteriorated quickly for resolutions below 10 lines.

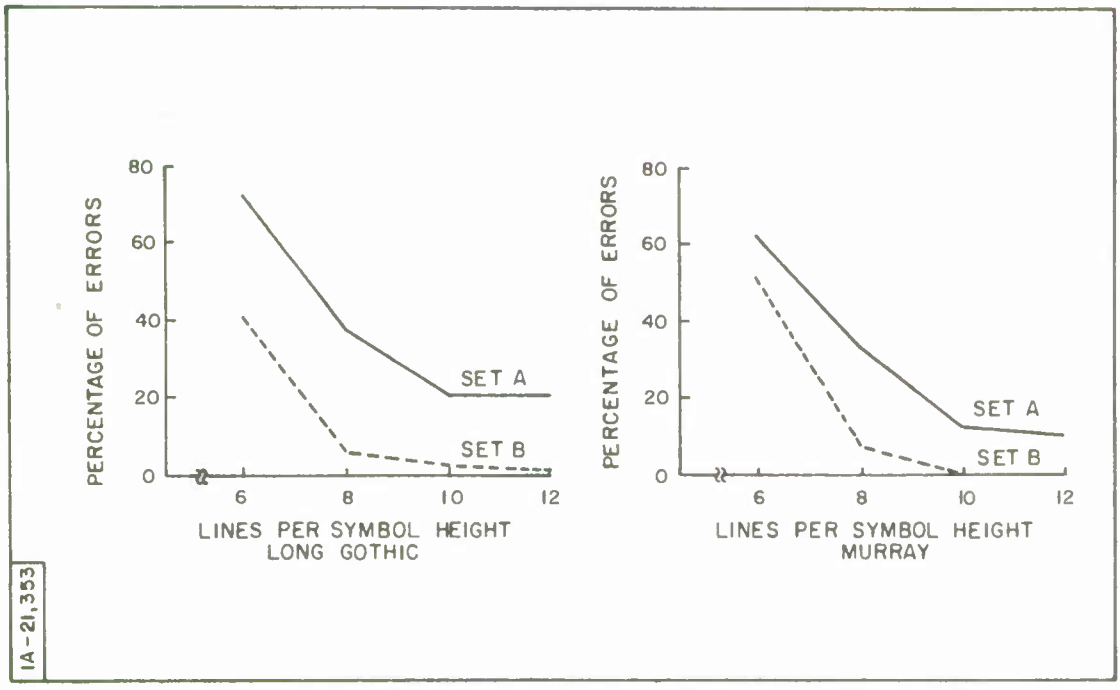

Figure 5. The Percentage of Errors Made by Three Subjects are Shown for Four Television Resolutions. Set A is ⦶, ⦷, and ⊕. Set B is ○ and the Alphanumeric Symbols.

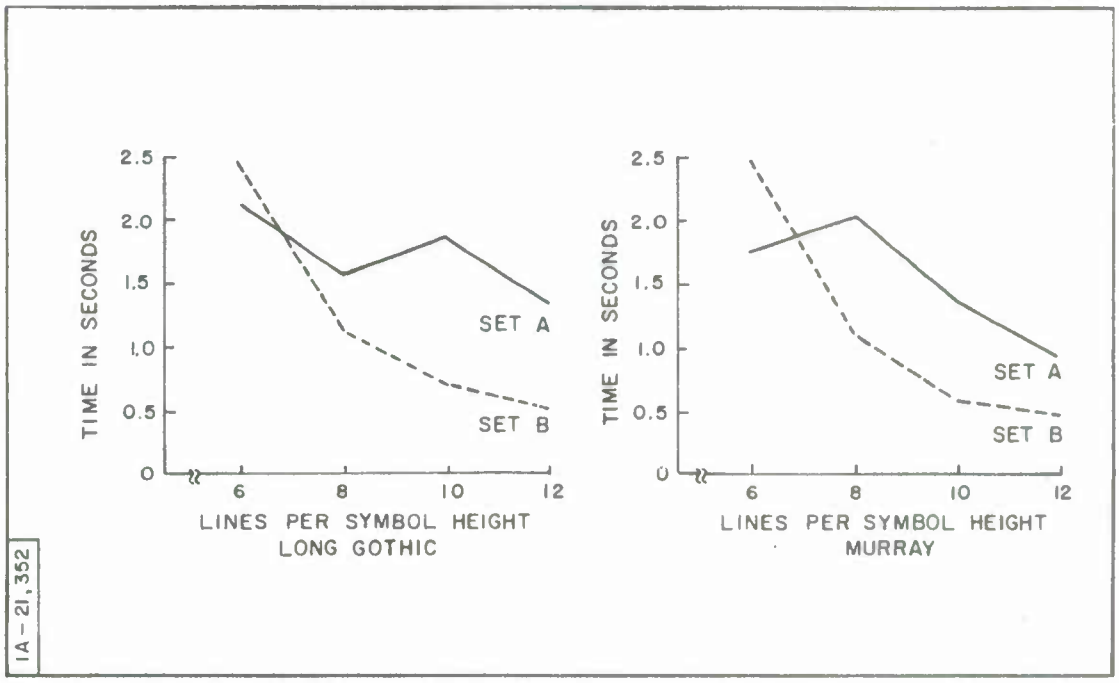

Figure 6. The Means of the Mean Response Times for Three Subjects are Shown for Four Television Resolutions. Set A is ⦶, ⦷, and ⊕. Set B is ○ and the Alphanumeric Symbols.

Conclusion 5. The minimum symbol resolution for television display of Long Gothic and Murray alphanumeric symbols is 10 active lines per symbol height under ideal conditions.

No obvious differences between the Long Gothic and Murray fonts could be seen in the data in this study. All the tables and figures show that percentage of errors and mean response times were closely similar for both fonts at the four resolutions tested.

Conclusion 6. There is no difference between the legibilities of Long Gothic and Murray alphanumeric symbols on television for the resolutions tested.

SECTION V

DISCUSSION AND RECOMMENDATIONS

This experiment, with light symbols on a dark background, indicates that both Long Gothic and Murray alphanumeric symbols require a minimum of 10 active lines per symbol height for use on television. The experiment was made with a television system which was adjusted each day, and with other conditions, such as symbol quality, brightness and contrast with background, controlled closely. It is very unlikely that day-to-day conditions would be so good in an operational display because the symbols would be typed on paper and would not be so sharply defined as the symbols in this experiment.

Two results of this study show no differences between the Long Gothic and Murray fonts when seen on television, and indicate strongly that the cloud-cover symbols ⦶, ⦷, and ⊕ are not sufficiently legible. A previous study with a tachistoscope reached similar conclusions.[1] Obviously, new cloud-cover symbols should be designed to make them at least as legible as the alphanumeric symbols used with them.

In a study of two other fonts on television, it was found that symbol identification is not improved by modifications of fine detail within the symbol outline.[7] Therefore, it is suggested that the cloud-cover symbols have different outline shapes so that the distinctive outlines will remain even if the internal details are blurred by television

scanning or a poor typewriter ribbon. Before conducting further experiments with television, a tachistoscope experiment has been planned which will study alternative symbols for ⦶ and ⦷, and at the same time will use actual typed symbols on paper from a teletype machine.

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13. ABSTRACT

The legibility of Long Gothic and Murray teletype symbol fonts was studied on television. Subjects identified light symbols on a dark background at four resolutions. The results showed that three special cloud-cover symbols were illegible for all resolutions studied. Under ideal conditions, 10 active lines per symbol height was the minimum recommended resolution for the alphanumeric symbols. The Long Gothic and Murray symbols were equally legible. It is recommended that more legible symbols be used for the three cloud-cover conditions.

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