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ABSTRACT

Limits of graphic display design component variation based on cognitive tolerance for imprecision were investigated using compatibility functions. The compatibility function is an empirical definition of a perceptual category representing the grade of membership of an implied physical attribute into a corresponding conceptual category, measuring the degree of compatibility between a particular level of attribute and a category. Adults (N=24) were asked to categorize lines as sharply or slightly increasing when presented with line and bar graphs with slopes from five to sixty degrees in five degree increments. Crossover point and precision parameters are discussed as part of the statistical analysis. This experiment established compatibility function values for the categorical terms sharply increasing and slightly increasing. A graph designer having an inventory of such functions plus the operations that can be performed on them can weight the information to be presented by manipulating various aspects of the graph, specifically the framework and/or specifier. This would allow graphs to be designed to meet specialized requirements. A list of twelve references, figures showing the types of graphs used, and the compatibility functions established fo the categories of interest to this experiment; and a table summarizing parameter values for the mathematical models are attached. (JM)

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A METHOD FOR PRAGMATIC COMMUNICATION IN GRAPHIC DISPLAYS

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INTRODUCTION

In the course of processing information graphic displays, the graph reader does not necessarily encode the visual information in a very precise quantitative way. Instead, the reader is likely to take this information, condense and summarize it to the extent demanded by the communicative context, and assign some linguistic label that captures the essense of its meaning (Zadeh, 1965, 1973; Zadeh, Fu, Tanaka & Shimura, 1975). In this way, irrelevant information does not load our processing system. Such a capability is essential if we are to stay within the capacity limits of our information processing system (Kahneman, 1973; Miller, 1956).

Sacrificing precision for a more cognitively manageable 'chunk' is usually sufficient for most human behavior since most of the basic tasks we perform do not require a great deal of precision for their execution. This tolerance for imprecision can be used to a graphic display designer's advantage, especially for inviting the reader to draw inferences and to be sensitive to connotations that are not explicitly present. However, the success with which the designer can accomplish this invited inference will depend on how well the physical properties of the display used to represent the specific message are matched to the reader's conceptual interpretation of it.

For example, suppose we want the graph reader to possibly infer from a display that the price of oil has sharply increased during the late 1970's. Without extreme exaggeration of this point (such as drawing a vertical trend line), we would like to choose the underlying slope of the displayed trend in oil prices in such a way that a reader's description of this underlying dimension includes a label of the perceptual category Sharply increasing.[1] This choice could be based on the designer's intuition, as is common practice. Alternatively, it is possible to define the meaning of terms like sharply increasing empirically and use the definition as the basis for choice. The meaning of a term defined in this way is called a 'compatibility function' (Kandel and Byatt, 1978; Rouse, 1980, Chap. 5).

The compatibility function represents the grade of membership of an implied physical attribute into a corresponding conceptual category. It measures the degree of compatibility between a particular level of attribute X and category P. Compatibility functions are defined on the interval [0,1] with the grades 1 and 0 representing, respectively, full membership and nonmembership in the category. For example, consider once again the class of sharply increasing trends. The question we ask is "what level of slope constitutes a sharp increase?" Is a slope of 40° perceived as a sharp increase? If so, is there a difference between a slope of 50° and one of 40°? Compatibility functions help us deal with such imprecise questions.

The purpose of this experiment is to determine compatibility functions for terms that have pragmatic implications in the communication of graphic information, specifically the terms sharply increasing and slightly increasing. Also, since Labov (1973) has shown that the context in which an object is viewed can influence compatibility, different contexts, in terms of different types of displays, are used.

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[1]Following Pinker's conjecture of graph comprehension (see Kosslyn, Pinker, Parkin & Simcox, 1982) the mental representation of a visual display is in terms of a predicate based structural description. Without going into detail, not only are quantitative paramaterized predicates sensed, e.g., slope(x) = x, but qualitative categories as well, e.g., slope(x) = sharply increasing.

METHOD

Subjects

Twenty-four fellow employees from CSI participated in the study. None were . for this participation. All subjects reported having normal visual acuity, six of which were corrected for.

Stimuli

Two types of graphs, line and bar graphs of the form shown in Figure 1, were used. For each graph type, a set of 12 graphs, each varying in slope from 5 to 60 degrees in 5 degree steps, was generated on a Tektronix 4027 graphics terminal. In terms of the framework, the graphs subtended a visual area of 12.7 x 12.7 degrees at a viewing distance of 51 cm. The distance between end-point of the specifier, projected onto the x-axes subtended an angle of 4.2 degrees.

INSERT FIGURE 1 HERE

Procedure

Subjects were seated in front of the graphics terminal at a distance of approximately 51 cm. They were told the purpose of the experiment and instructed to indicate by a yes or no as to whether the slope of the line satisfied the appropriate perceptual category. Each particular graph was activated by depressing a unique key on the keyboard, that key being consistent across subjects. Subjects were told by the experimenter which particular key to activate prior to each presentation. The appropriate key was then depressed and the graph appeared. Although the task was self-paced, subjects were prompted for an answer after a 5 second interval from onset of the graph. Answers were manually recorded by the experimenter and subjects depressed the erase key, clearing the screen for the next presentation. An experimental session lasted about 30 minutes.

Design

Each subject performed 2 blocks of 48 categorizations with a short rest period between blocks. The 48 categorizations resulted from the combination of 12 slopes (5 to 60° by 5° increments), 2 graph types (line/bar), and 2 classifying terms (sharply/slightly increasing). The order of categorization was balanced in a latin square arrangement, each block corresponding to one row of the square. For each subjec , responses to both blocks were combined and compatibility functions were determined by averaging across all subjects.

Results and Discussion

Compatibility functions defining the terms <u>slightly increasing</u> and <u>sharply increasing</u> for both graph types are shown in Figures 2 and 3 respectively. Each point represents the relative frequency of yes responses for 48 categorizations (i.e., 24 subjects x 2 replications). Thus, for example, from figure 3 the degree to which a numerical slope, say $x = 30°$, is compatible with the concept <u>sharply increasing</u> is 0.37, while the compatibilities of 40° and 50° are 0.80 and 1.00 respectively.

INSERT FIGURES 2 AND 3 HERE

In many cases it is convenient to express compatibility functions in terms of a standard function whose parameters may be adjusted to fit a specified compatibility function. Since the given task required subjects to discriminate between stimuli that were possible instances of the category in question from stimuli that were not, the logistic function of the form

$$\mu_i(x_j) = \frac{1}{1 + e^{a(x_j - b)}}$$

or (1)

$$\mu_i(x_j) = \frac{e^{a(x_j - b)}}{1 + e^{a(x_j - b)}} \qquad i=1,2$$

was taken as the mathematical representation of the compatibility function for slightly or sharply increasing respectively, over the interval where they exist (see Luce, 1959, Luce, Bush & Galanter, 1963 for a description and use of this function in discrimination research). In this equation, $\mu_i(x_j)$ represents the degree of compatibility of a stimulus having value x_j with category i. Two free parameters of this model, estimable from the data, are the crossover point (b) and the category precision parameter (a). The crossover point--defined as the value of the attribute at which compatibility is 0.5--represents the numerical value of the implied attribute that results in the greatest uncertainty regarding possible membership or nonmembership in a given category. The precision parameter provides an indication of the extent to which a category is well defined in the sense that a given instance is either a member of the category or is not a member. It measures how quickly the uncertainty regarding membership or nonmembership decreases as values of the attribute move away from the crossover point.

The model of equation (1) was used to fit the data generated under each of the four conditions with the resulting parameter values and 95 percent confidence limits shown in Table 1.[2] From the table, we can see that the precision parameter is independent of the graph type since each estimated value lies inside every confidence interval. This means, for example, that a 15° increase in slope from the crossover point of a line graph would correspond to the same degree of compatibility with the term sharply increasing as would a 15° increase in a bar graph.

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[2]The curve fitting was done by the Statistical Analysis Ststem's (SAS) non-linear regression procedure (PROC NLIN) using the derivative free algorithm of Ralston & Jennrich (1978).

INSERT TABLE 1 HERE

However, the actual slope values underlying this categorization would not be the same since the crossover points are different. Note that the crossover points correspond to larger slope values in line graphs than bar graphs. With regard to the term sharply increasing, this means that the slope of a line graph must be somewhat larger than the slope of a bar graph to achieve the same degree of compatibility with the term. Conversly, for the term slightly increasing, the slope represented in a bar graph must be somewhat smaller than that for a line graph to achieve the same degree of compatibility.

Zadeh (1973) has defined a number of operations that can be performed on compatibility functions, one of which is complementation. The complement of $\mu_i(x_j)$, represented notationally as $\mu_{\bar{i}}(x_j)$ and linguistically by the label not, is defined as

$$\mu_{\bar{i}}(x_j) = 1 - \mu_i(x_j) \qquad (2)$$

From the parameter values shown in Table 1, one can see that for the stimuli used in this experiment slightly increasing is not the same as not sharply increasing since the relationship defined by equation (2) does not hold.

DISCUSSION

We can think of compatibility functions as the meanings of the categorical terms they represent. Armed with an inventory of such functions plus the operations that can be performed on them, a graph designer can connotatively weight all sorts of information. However, this connotative weighting must be acheived by manipulating certain aspects of the graph, specifically the framework and/or specifier. How this is done is considered more fully in Kosslyn, Pinker, Parkin & Simcox (1982), but for illustrative purposes consider the following example.

Suppose that in a recessionary period a company executive wants to emphasize the positive aspects of his or her company's revenue growth, though not very large, to the group of listeners. He or she has revenue figures per month over the last six months as data. Although the trend is not to be overly exaggerated, some compatibility with the term <u>sharply increasing</u> is desired to emphasize the point. Therefore, a compatibility of 0.70 is chosen. For a presentation using a bar graph, this corresponds to an underlying slope of 32 degrees. Defining the aspect ratio of a framework (see Kosslyn et al, 1982) as the ratio of vertical axis length to horizontal axis length, this slope can be achieved using an aspect ratio of 0.62:1. Thus, physically, the vertical scale must be 0.62 the size of the horizontal scale.

There are many other similar examples where one would like the graph reader to react more strongly to a presentation of data then might be warranted otherwise. For example, in a process control setting, if a parameter is to be held at a very tight tolerance and its measurement presented graphically, as in a control chart, changing the aspect ratio to emphasize small changes is more than justified. An inventory of such functions allowing a rational basis for designing such graphs would go a long way towards fulfilling these sorts of display needs.

References

Kahneman, D. Attention and Effort, Englewood Cliffs, NJ: Prentice Hall, 1973.

Kandel, A. & Byatt W.J. Fuzzy sets, fuzzy algebra, and fuzzy statistics. Proceedin of the IEEE, 1978, 66(12), 1619-1639.

Kosslyn, S.M., .inker, S., Parkin L.P. & Simcox, W.A. Understanding Charts and Graphs: A Project in Applied Cognitive Science, 1982.

Labov, 1973

Luce, R.D. Individual Choice Behavior, New York: Wiley, 1959.

Luce, R.D., Bush, R.R. & Galanter, E. (Eds) Handbook of Mathematical Psychology, New York: Wiley, 1963.

Miller, G.A. The majical number 7±2: Some limits on our capacity for processing information. Psychological Review, 1956, 63(2), 81-97.

Ralston, M.L. & Jennrich, R.I. DUD, A derivative-free algorithm for nonlinear least squares. Technometrics, 1978, 20(1), 7-14.

Rouse, W.B. Systems Engineering Models of Human-Machine Interaction, New York, North Holland, 1980.

Zadeh, L.A. Fuzzy sets. Information and Control, 1965, 8, 338-353.

Zadeh, L.A. Outline of a new approach to the analysis of complex systems and decision process. IEEE Transations on Systems, Man, and Cybernetics, 1973, 3(1), 28-44.

Zadeh, L.A., Fu, K.S., Tanaka, K. & Shimura, M. (Eds). Fuzzy Sets and Their Applications to Cognitive and Decision Processes, New York: Academic Press, 1975.

List of Figures & Tables

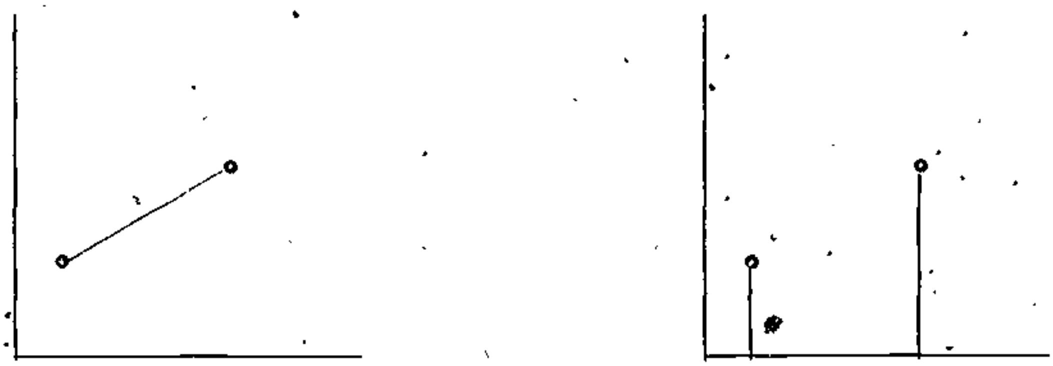

FIGURE 1 - GRAPH TYPES USED IN EXPERIMENT

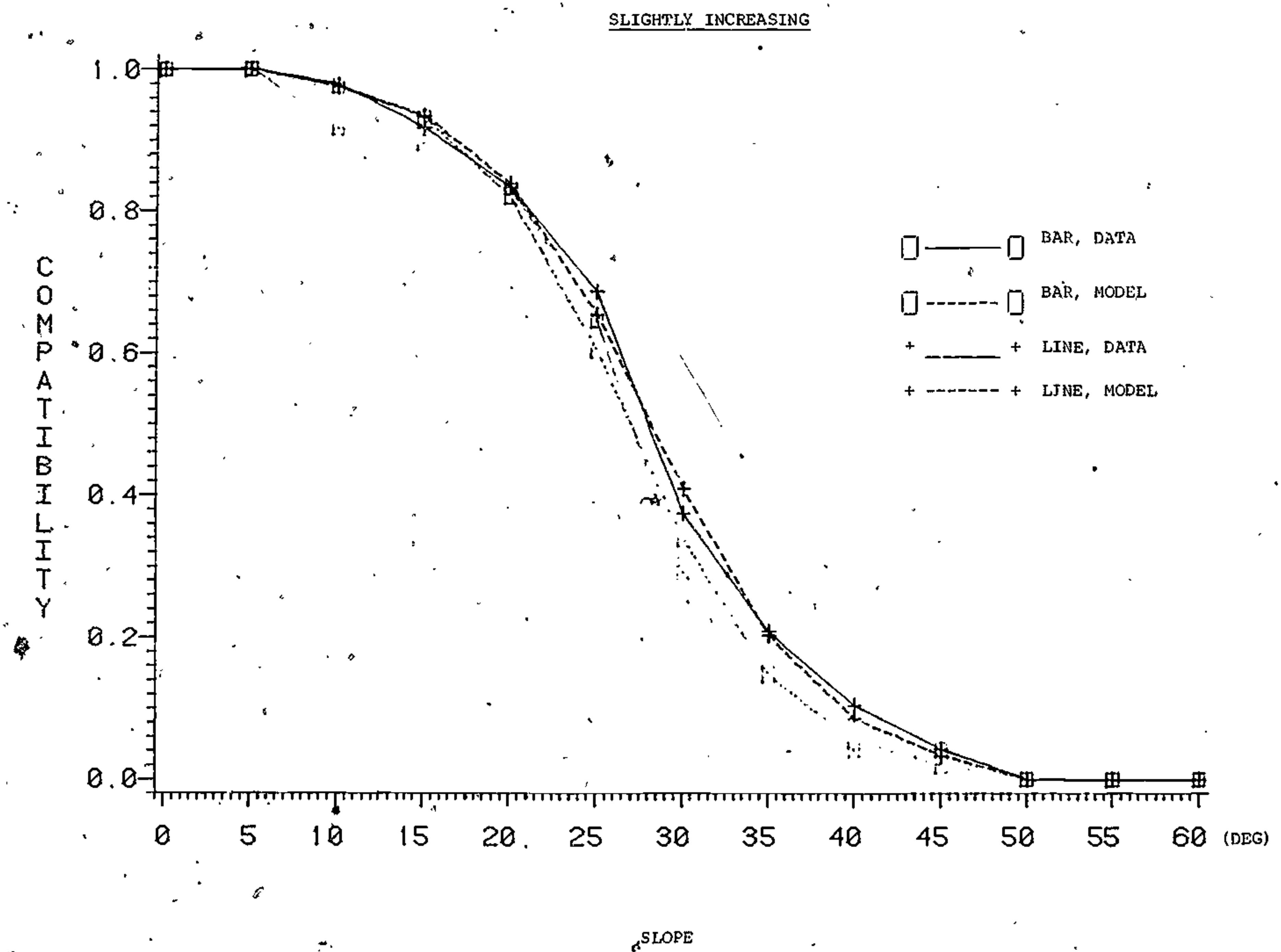

FIGURE 2 - COMPATIBILITY FUNCTIONS FOR CATEGORY SLIGHTLY INCREASING

SHARPLY INCREASING

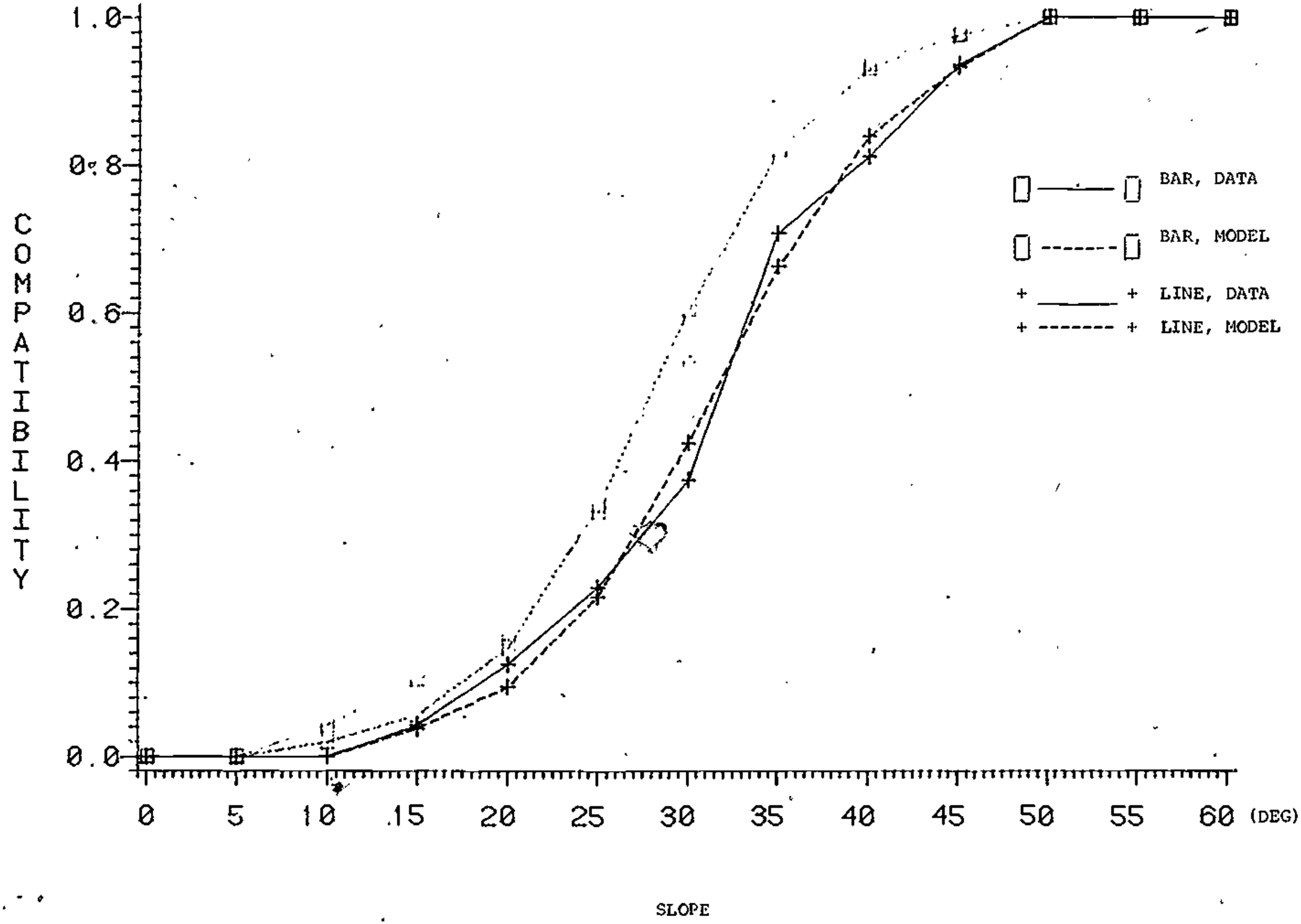

FIGURE 3.- COMPATIBILITY FUNCTIONS FOR CATEGORY SHARPLY INCREASING

TABLE 1

Parameter Values of Mathematical Models
Used to Represent the Compatibility Function

Graph Type	Label	Precision Parameter	Confidence Interval	Crossover Point	Confidence Interval
LINE	Sharply	0.196	[0.170,0.221]	31.550	[30.802,32.306]
	Slightly	0.201	[0.183,0.219]	28.177	[27.681,28.673]
BAR	Sharply	0.218	[0.178,0.258]	28.023	[27.066,28.981]
	Slightly	0.218	[0.183,0.252]	26.940	[26.113,27.770]