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RELIABILITY VS. DIAGNOSTICITY
IN HIERARCHICAL INFERENCE

BY

GREGORY M. GRIFFIN

AND

WARD EDWARDS

SPONSORED BY

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PRIME CONTRACT MDA903-80-C-0194
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SSRI-81-3	2. GOVT ACCESSION NO. AD-A105628	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Reliability vs. Diagnosticity in Hierarchical Inference.	5. TYPE OF REPORT & PERIOD COVERED Research Report	6. PERFORMING ORG. REPORT NUMBER SSRI-81-3
7. AUTHOR(s) Gregory M. Griffin and Ward/Edwards	8. CONTRACT OR GRANT NUMBER(s) MDA903-80-C-0194	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Social Science Research Institute, Univ. of So. Ca. University Park, Los Angeles, CA 90007	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 12137	
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency DSO/CTD, 1400 Wilson Boulevard Arlington, VA 22209	12. REPORT DATE June 1981	13. NUMBER OF PAGES 19
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Decisions and Designs, Inc. 8400 Westpark Drive, Suite 600; P.O. Box 907 McLean, VA 22101	15. SECURITY CLASS. (of this report) UNCLASSIFIED	16. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Cascaded inference and hierarchical inference.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This study examined the performance of subjects in a cascaded inference task where two subjects worked together, one subject having diagnosticity information and the other having reliability information. This was compared to a condition in which a single subject received both types of information. Additionally, the effects of different "experts" having the power to make the final decision in the two-person conditions was explored. Seventy-two subjects made inferences about the probability of success vs. failure of hypothetical job applicants presented in a personnel manager scenario.		

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SUMMARY

This study examined the performance of subjects in a cascaded inference task where two subjects worked together, one subject having diagnosticity information and the other having reliability information. This was compared to a condition in which a single subject received both types of information. Additionally, the effects of different "experts" having the power to make the final decision in the two-person conditions was explored. Seventy-two subjects made inferences about the probability of success vs. failure of hypothetical job applicants presented in a personnel manager scenario. Subjects were paid bonuses according to their performance on the task.

Contrary to hypotheses, there were no between conditions differences. Single subjects performed just as well as subjects working together. This study replicates previous work using single subjects in the general pattern of responses: subjects were somewhat radical in comparison to the normative model.

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ACKNOWLEDGEMENT

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Office of Naval Research, prime contract MDA903-80-C-0194, under subcontract from Decisions and Designs, Inc. Special thanks go to Richard S. John, William G. Stillwell and Detlof von Winterfeldt, whose valuable comments aided in the execution and reporting of this research.

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INTRODUCTION

Some of the most important and interesting information processing tasks that men and women in the real world face are essentially hierarchical (or cascaded) in nature and involve different people with different types of information that must be combined. In a large class of such hierarchical tasks a distinction is made between the diagnostic impact of a piece of information and its reliability. In a legal context, for example, a witness may testify about having seen the defendant on the scene of the crime. This piece of information might be relevant to whether or not the defendant committed the crime. In order to degrade the diagnostic impact of the piece of information, the defense attorney may try to establish that the witness' testimony is unreliable. Schum (Notes 1 & 2) has formalized hierarchical structures like these and a substantial empirical literature exists on how people perform in simple cascaded inference tasks (e.g. Peterson, 1973).

The normative formula for calculating posterior odds (in terms of the probability forms of reliability (R) and diagnosticity (D)) assuming equal priors and symmetric reliability and diagnosticity is:

$$\text{Post. Odds} = (2RD - R - D + 1) / (-2RD + D + R)$$

This assumes equal priors, symmetric reliability, and symmetric diagnosticity.

Most of the empirical research on hierarchical inference had a single person process both diagnosticity and reliability information. Typically, these experiments have found that subjects were radical in comparison to the normative responses specified by Modified Bayes Theorem (MBT) (Gettys and Willke, 1969). That is, the unreliability of the report of the diagnostic event was taken into account, but not enough. In contrast to this single person paradigm, many real world inference problems involve different experts, some with diagnosticity expertise and some with reliability expertise. It is at least questionable whether the single person results would generalize to the multiple expert inferences. Specifically, one might expect the reliability information to be taken into account more strongly when the use of the information is advocated by a person with special expertise in reliability.

The present experiment examined this hypothesis by comparing the relative impact of reliability and diagnosticity in a single vs. two person paradigm, in which one person had reliability information and the other had diagnosticity information. We also used a power manipulation in the two person groups which gave the ability to make the final decision on the response to either the

reliability or the diagnosticity "expert". We felt that this power manipulation would affect the relative impact of the reliability and diagnosticity information.

The early experiments in cascaded inference usually used a paradigm in which subjects performed a sampling task or a difficult perceptual task. These laboratory tasks do not parallel any real world tasks. Furthermore, subjects must first make a judgement about the probability of the event and then aggregate that judgement with the diagnostic impact of the event. Schum's normative models closely parallel complex real-world hierarchical tasks, but do not provide the specific correct inputs into the models, so a numerical comparison between subjects' responses and the normative responses is difficult to make.

In this study we asked subjects to role play the parts of personnel officers evaluating job applicants for positions as electronics repairpersons.

Subjects received training in the interpretation of diagnosticity, reliability, or both; and saw probabilities and likelihood ratios representing their information. The fairly detailed, pilot tested scenario provided a setting in which to present pass/fail test scores for the hypothetical job applicants that had a specific diagnostic impact on the probability of success on the job, along with reliability information on the pass/fail score. The goals of the design were as far as possible to combine an interesting task with availability of a normatively correct solution, and to focus

attention on the hierarchical nature of the task.

METHOD

Subjects

Subjects were 41 male and 31 female undergraduates enrolled in an introductory psychology course at the University of Southern California. Subjects signed up for and participated in several hours of research in partial fulfillment of class requirements.

Materials and Stimuli

The scenario included some training in the use of probability and odds. Depending on the condition to which subjects were assigned the instructions included information about the meaning of reliability, diagnosticity, or both.

We presented the diagnosticities and reliabilities on forms that contained relative frequencies, probabilities, and odds. Subjects responded in odds on a logarithmically spaced response scale (log-odds scale). The scale was symmetric around "1 : 1" with endpoints of "1000 : 1" and "1 : 1000".

Procedure

Subjects were randomly assigned to one of four experimental conditions: In condition 1 subjects worked alone and received both the reliability and diagnosticity information. In condition 2, subjects worked in pairs. One member of each pair received diagnosticity information and training; the other received similar information and training about reliability. The pair was asked to reach a consensus

judgement. Conditions 3 and 4 were identical to condition 2 except that either the diagnosticity expert (condition 3) or the reliability expert (condition 4) was given the power to overrule the other subject on the final response.

The experimenter assigned subjects to their roles with a flip of a coin, in their sight. The experimenter then read aloud the general set of instructions to the subjects while they had a copy of them. General instructions contained a scenario description, a summary of the type of information to be provided, a description of how bonuses were to be awarded (using a modification of the quadratic scoring rule), and a brief lesson on the use of probability and odds.

The experimenter encouraged subjects to ask questions when confused and quizzed them on key points.

The experimenter then read and discussed the instructions on the diagnosticity information (to the diagnosticity expert alone in the two person conditions). These instructions contained information about the probabilistic meaning of diagnosticity, the presentation of the diagnosticities, and how the diagnosticities would vary. Next, the experimenter presented the reliability instructions (separately to the reliability expert in the two person conditions) answering the same set of questions about the reliabilities. Covering the full set of instructions took about 30 to 75 minutes depending on how much help subjects needed.

Subjects then worked through two practice trials. During practice trials, subjects were free to ask questions. After each practice trial, the experimenter questioned the subjects to determine if they understood the meaning of their response, in terms of the relative chance of success/failure of the hypothetical job applicant.

Occasionally subjects revised their odds in the incorrect direction. We assumed this indicated that subjects did not fully understand the task. If this occurred during the practice trials, the experimenter encouraged subjects to rethink their responses (but they were not required to change them.) (During data collection trials if this happened the meaning of the response was explained again. This happened rarely.)

The subjects then ran the 12 data collection trials. The experimenter scored a subset of eight of the trials and paid each subject a bonus of three to five dollars, awarded according to their performance as scored by a modified form of the quadratic scoring rule.

The same experimenter ran all subjects.

RESULTS

Design

The between groups variable was the four conditions described previously. Ten full sets of responses were collected in each condition (except in condition 4 where 11 full sets were collected by mistake.) Therefore, there were 10 subjects in condition 1, 20 in conditions 2 and 3, and 22

in condition 4.

Within subjects both reliability and diagnosticity varied at six levels. The levels were .60, .67, .75, .80, .90, and .95. However, the six levels of each were not fully crossed, but grouped as three sets of 2 x 2's thus yielding the 12 trials. Within any one of the 2 x 2's, the cells off the diagonal yielded the same final normative probability. The three 2 x 2's and the normative final probabilities are presented in Table 1.

Insert Table 1 about here.

Analyses

ANOVA's. Preliminary ANOVA's were run on "reflected" log-likelihood ratios. (Normative odds were both greater and less than unity. For the purpose of analysis, the reciprocal of the raw response and of the normative response was taken on trials in which the normative result was less than unity before being logged for all analyses unless otherwise noted.) A separate ANOVA was run on each of the 2 x 2's. The F ratio for the between subjects manipulation did not approach a level of classical significance. This was unexpected since one of the differences between conditions is that condition 1 had only single subjects working alone whereas the other conditions had two subjects working together.

TABLE 1

Level of Reliability, Diagnosticity, and Normative Probability

Reliability	Diagnosticity	Normative Probability
.9	.9	.820
.9	.75	.700
.75	.9	.700
.75	.75	.625
.95	.95	.905
.95	.6	.590
.6	.95	.590
.6	.6	.520
.8	.8	.680
.8	.67	.602
.67	.8	.602
.67	.67	.558

For the within subject variables (diagnosticity and reliability), diagnosticity was highly significant ($P < .0001$) in all three of the 2×2 's. Reliability was significant in two of the 2×2 's ($P < .0001$ & $P = .002$). An interaction of reliability and diagnosticity was significant in one ($P = <.0104$). The mean log-likelihood ratios are plotted in Figure 1, collapsing over condition.

Insert Figure 1 about here.

The general picture that emerges is that diagnosticity has a large effect, reliability has a smaller effect, and possibly there is an interaction which indicates that reliability has a greater effect at the higher levels of diagnosticity.

For closer examination of the data we used individual correlational and regression analyses.

Correlational and regression analyses. Table 2 shows correlational analyses on a subject by subject basis.

Insert Table 2 about here

All of these analyses were performed on the log-likelihood ratios obtained in the following ways and the log of the odds that the subjects gave. Row 1 used the full-range normative likelihood ratios (and responses), row 2 used responses and normative likelihood ratios that are reflected

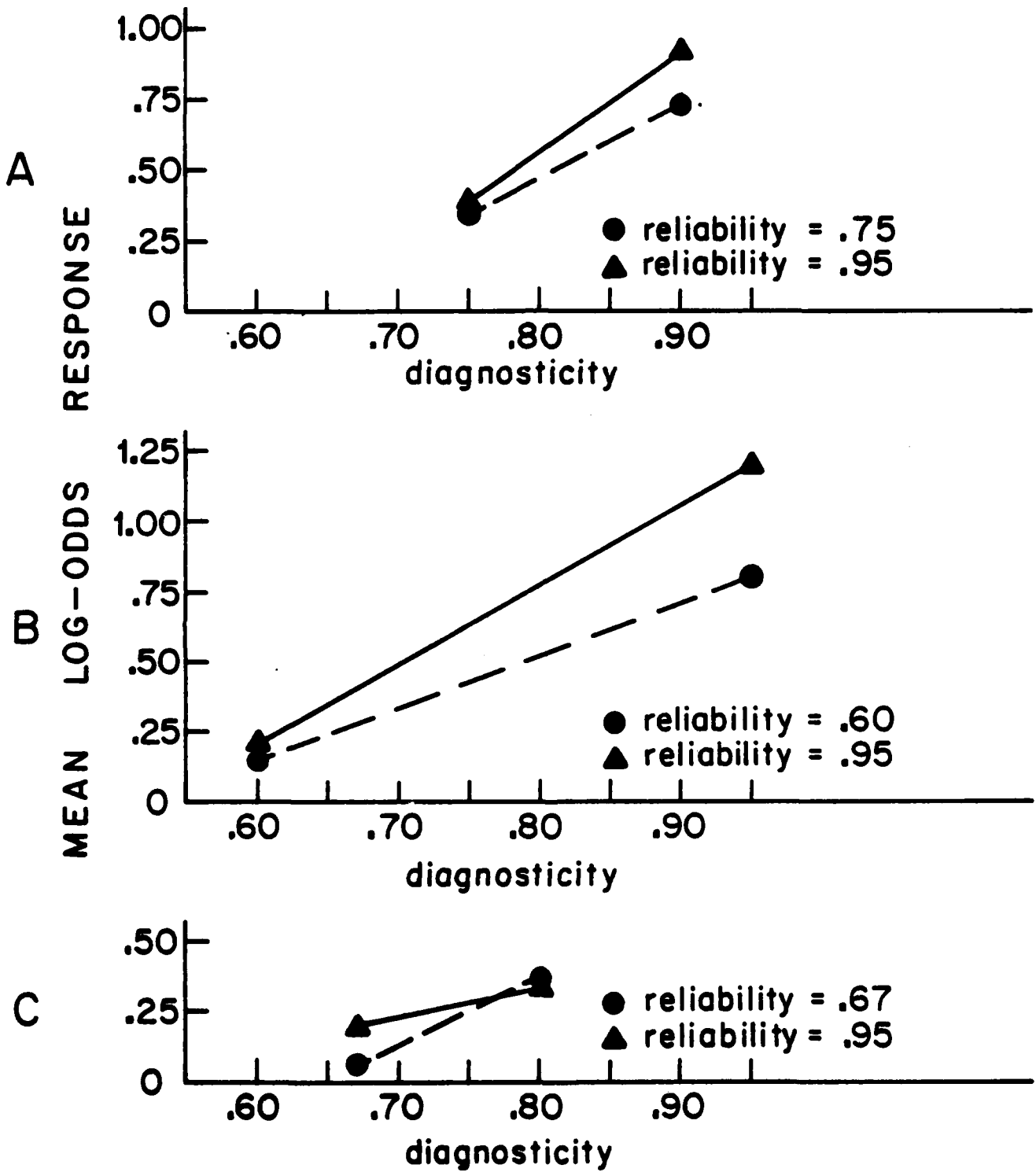


Figure 1: Mean Log-Odds Responses for Varying Levels of Reliability and Diagnosticity

TABLE 2
Correlation Means and Standard Deviations for Logs of Responses
with Logs of Normative Result and Various Heuristics

COMPARISON	CONDITION 1		CONDITION 2		CONDITION 3		CONDITION 4		GRAND MEAN
	X	SD	X	SD	X	SD	X	SD	
Optimal (non-reflected)	.872	.130	.900	.056	.864	.086	.854	.055	.872
Optimal (reflected)	.733	.230	.726	.201	.727	.151	.673	.112	.714
Reliability	.364	.227	.359	.169	.327	.185	.282	.158	.332
Diagnosticity	.714	.239	.779	.227	.859	.093	.779	.254	.783
Minimum (D,R)	.690	.238	.640	.231	.651	.159	.604	.115	.645
P(R) X L(D)	.744	.230	.744	.195	.770	.149	.706	.124	.740
P(R) X P(D)	.755	.234	.811	.219	.855	.087	.804	.225	.806
P(R) X log L(D)	.736	.220	.743	.275	.853	.010	.774	.199	.776
L(D) ^R	.786	.219	.828	.198	.877	.091	.805	.196	.823

so that all are greater than or equal to unity. All of the rest of the rows also used reflected responses and likelihood ratios. Rows 3 and 4 used, respectively, the likelihood ratios obtained just by using the reliability or diagnosticity information. Row 6 used reliability times diagnosticity, both in probability form, and then converted to likelihood ratio form. Row 7 multiplies reliability in probability form times the likelihood ratio form of diagnosticity; and row 8 uses the likelihood ratio of diagnosticity raised to a power equal to the probability form of the reliability. (Formulas are in Table 2.) As in the ANOVA, no interpretable differences among conditions were found.

Table 3 presents sample statistics computed on the slopes obtained using the log of the reflected obtained likelihood ratios as the dependent variable and the log of the normative reflected likelihood ratios as the independent variable.

Insert Table 3 about here.

Again, no interpretable differences between conditions are found. The high correlations with the normative responses and the slightly greater than unity betas of Table 3 indicate that subjects do a generally good job on the hierarchical task. The betas indicate that subjects are somewhat radical in their probability estimates--essentially

TABLE 3
Sample Statistics for Slopes
of Log Responses with Log Normative Odds

	Condition 1	Condition 2	Condition 3	Condition 4
Median	1.15	1.13	1.23	1.17
Mean	1.0990	1.0508	1.2330	1.2287
Standard Deviation	.195	.275	.142	.327

the typical finding. Figure 2 plots the mean log likelihood ratio for each of the 12 trials against the normatively correct log likelihood ratio, collapsing across individuals and conditions.

Insert Figure 2 about here.

This also demonstrates the general pattern of radicalness.

Rows 3 and 4 of Table 2 (the correlations of obtained log likelihood ratios with those obtained from the reliability and diagnosticity levels used in the experiment) yield correlations which indicate that subjects relied more heavily on diagnosticity than reliability in making their inferences. (An examination of the normative formula provided earlier shows that each should be used equally in making the inferences.) Again, there were no interpretable between conditions differences.

The last four rows of Table 2 briefly examine four possible heuristics of which the likelihood form of diagnosticity, $L(D)$, raised to the probability form of reliability, $P(R)$, provides the best fit to the data. However, examination of the individual correlations (which are not provided in this report) shows individual differences in what the subjects seemed to be doing.

DISCUSSION

This study has two main conclusions: that reliability information in general is not used appropriately which leads

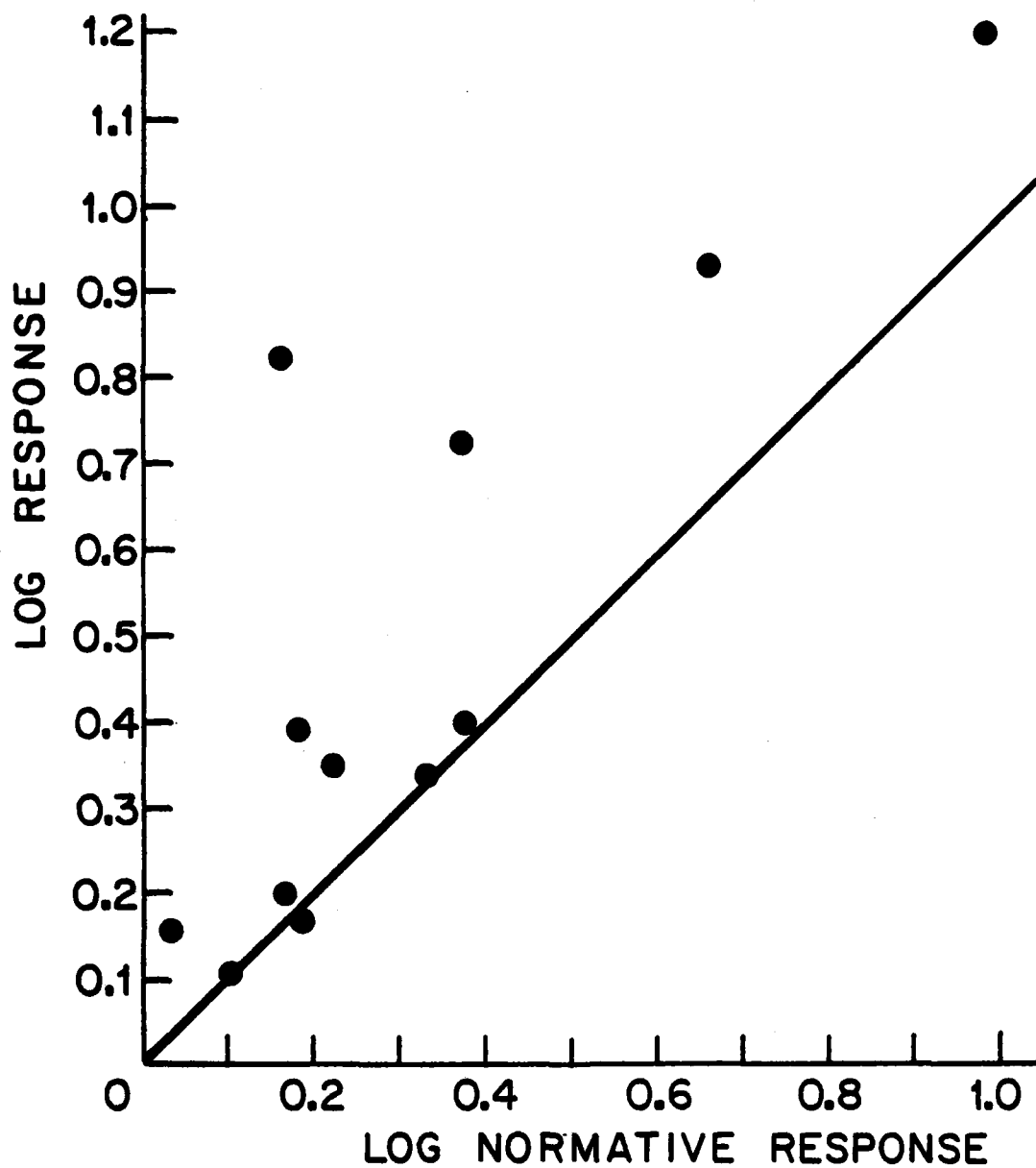


Figure 2: Mean Log-Odds Responses Plotted on Normative Log-Odds Results

to radicalism in probability estimates, and that different individuals working together, each receiving different types of information, respond much the same as would an individual working alone.

The former conclusion is a replication of the standard finding in cascaded inference (e.g., see Peterson et al., 1973). Schum, Du Charme, and DePitts (1973) suggest a possible explanation: it is non-obvious how unreliability degrades likelihood ratios, especially when they are large. Panel A of Figure 3 demonstrates this normative phenomenon.

Insert Figure 3 about here.

However, if instead of looking at adjusted likelihood ratios we examine adjusted conditional probabilities, the non-linearity of the appropriate degradation disappears (Panel B). This suggests that a log-odds scale may not be the most appropriate response mode for cascaded tasks.

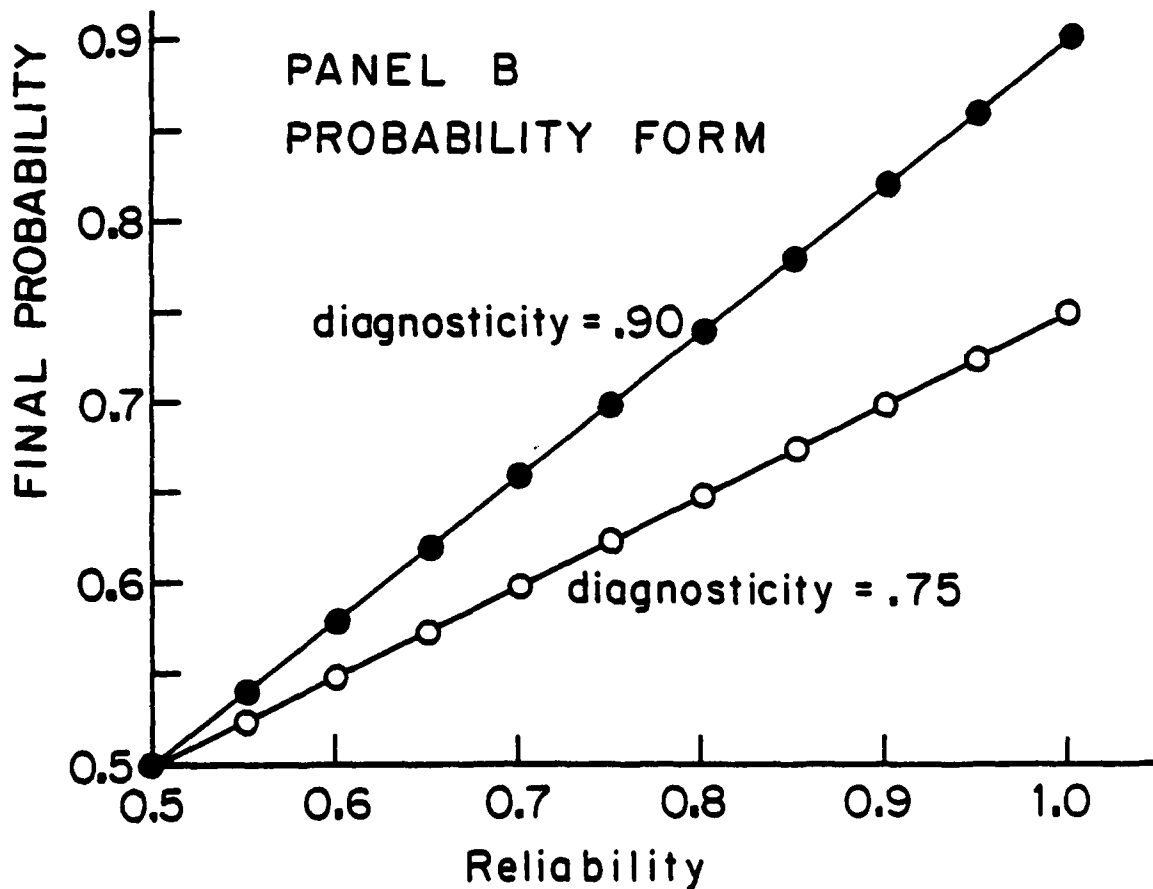
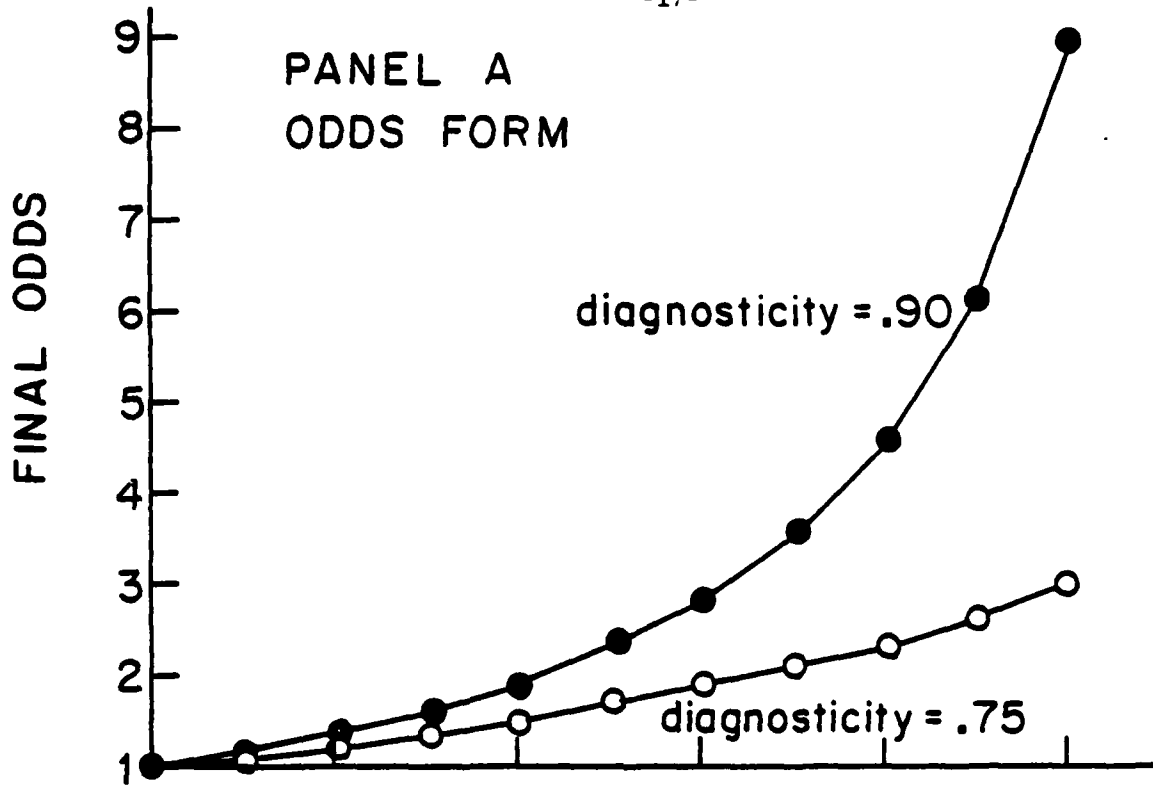


Figure 3: Comparison of Normative Final Odds vs. Normative Final Probability for Hierarchical Inference

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