December 2001

A Model for and the Effects of Information Request Ambiguity on End-user Query Performance

Micheal Axelsen
Univesity of Queensland

A. Faye Borthick
Georgia State University

Paul Bowen
University of Queensland

A MODEL FOR AND THE EFFECTS OF INFORMATION REQUEST AMBIGUITY ON END-USER QUERY PERFORMANCE

Micheal Axelsen
Department of Commerce
University of Queensland
micheal_axelsen@horwath.com.au

A. Faye Borthick
School of Accountancy
Georgia State University
borthick@gsu.edu

Paul L. Bowen
Department of Commerce
University of Queensland
bowen@lorien.commerce.uq.edu.au

Abstract

The increasing reliance of organizations on information technology, which prompts everyone to expect faster responses to information needs, is propelling end users to satisfy many information requests they receive by querying databases themselves. This paper develops and tests a model for the effects of information request ambiguity on end-user query performance where performance is measured by the number of errors in user-developed queries, the time taken to complete queries, and end users' confidence in the correctness of their queries. Based on preliminary analysis of participants' performance, end-user query performance was significantly degraded by the presence of ambiguity in information requests. The model identifies seven ambiguities: lexical, syntactical, inflective, pragmatic, extraneous, emphatic, and suggestive. Organizations whose participants rely on e-mail to communicate information requests or whose work teams experience rapid personnel turnover may be especially vulnerable to the debilitating effects of ambiguities on information requests.

Keywords: Ambiguity, end-user querying, natural language queries, query errors.

RESEARCH OBJECTIVES AND QUESTIONS

Because organizations perceive the need to access more information faster to ensure organizational responsiveness, more end users are developing their own database queries to get the information they need when they need it. But while they may be familiar with the information they want, end users may not be proficient at transforming their natural language information requests into queries that will get them the information they want.

Query errors increase with the complexity of information requests (Jih et al. 1989), and there is some evidence that end-user query errors increase with increasing ambiguity of the information request (Borthick et al. 2001). Ambiguity, the potential for multiple interpretations, arises in information requests because of the inherent ambiguity in natural language. That is, because the natural language in which users express the need for information is ambiguous, a query developed to respond to an information request may not represent the correct interpretation of the request. This ambiguity creates the potential for legitimate multiple interpretations of an information request, only one of which may be what was intended.

Information request ambiguity may have large impacts on organizations although end users may not be aware of them. If incorrect query results are relied upon for decisions that the right results would not have supported, then information request ambiguity may be associated with substantial negative outcomes.

THEORETICAL FOUNDATIONS

Ambiguity in Natural Language

Because they are expressed in natural language, information requests may be ambiguous, which means that multiple interpretations of the requested information may be constructed legitimately (Almuallim et al. 1997). In the absence of ambiguity, users map their conceptualization of the information requirement to the database structure through the constructs of the query language (Reisner 1977). The presence of ambiguity, however, ensures that users have more cognitive processing to perform. Users recognizing and attempting to resolve ambiguities expend additional mental effort. Although this additional mental processing may help avoid query errors, the extra mental effort will take time, which means users will be able to complete fewer queries. Users formulating queries without recognizing the existence of multiple interpretations forego the additional mental effort but are more likely to misinterpret the information request, thus increasing the number of query errors. Furthermore, the mental activity of resolving ambiguity, because it puts users on notice of the possibility of multiple interpretations, tends to decrease users' confidence in the correctness of their queries. These tendencies can be stated as hypotheses:

H1a: Higher ambiguity in information requests is associated with more errors in queries.
H1b: Higher ambiguity in information requests is associated with increased time for query development.
H1c: Higher ambiguity in information request is associated with lower user confidence in the correctness of queries.

Ambiguity Types

Since Aristotle, philosophers have wrestled with the effects of language ambiguity on understanding. Depending on the information need, ambiguities may affect the number of legitimate interpretations of the natural language statement of the information request (Walton 1996). The seven types of language ambiguities illustrated in Table 1 are potentially relevant to query development: lexical, syntactical, inflective, pragmatic, extraneous, emphatic, and suggestive.

To test the effects of these potential sources of ambiguity, hypotheses of the following form are proposed for each of the seven ambiguity types:

Hxa: Higher _____ ambiguity in information requests is associated with more errors in queries.
Hxb: Higher _____ ambiguity in information requests is associated with increased time for query development.
Hxc: Higher _____ ambiguity in information requests is associated with lower user confidence in the correctness of queries.

METHOD

A laboratory experiment was conducted to test the hypotheses in a one-factor (clear or ambiguous formulation of the information request) with two covariate (complexity of the information request and grade-point average) within-groups experimental design. Participants satisfied a sequence of information requests by preparing and executing Oracle SQL queries under the control of Unix scripts, which captured queries and query results in text files, including start and end times for each request.

After each query attempt was executed, the system displayed the SQL result. Participants could revise their queries as many times as they wished. When they indicated they were satisfied with the result for a request, participants were prompted to specify their confidence that the query result was correct. After indicating confidence levels, participants began work on the next request.

Participants, advanced undergraduate and postgraduate IS students, had been previously trained in the use of the SQL query language and had practiced using SQL. Generally, participants' expertise with SQL was low to intermediate. For assignment to group A or B, participants were first stratified according to their information systems and query experience and skill and then randomly assigned to a group.

Table 1. Ambiguity Types in Information Requests

Ambiguity Type	Information Request and Explanation
Lexical	A report of our clients for our marketing brochure mailing. The word "report" may have several meanings, independent of its context. For example: a gunshot report echoing through the hillside; the Lieutenant reported to the Captain; I dropped the heavy report on my toe, etc. Although the context may make the meaning clear, the lexical ambiguity adds to cognitive effort and contributes to ambiguity overall.
Syntactical	A report of poor-paying clients and client managers. Determine their effect on our profitability for the last 12 months. It is not clear whose effect on profitability is meant. Another example is "Bob hit the man with a stick." It is not clear, syntactically, whether the man with a stick was hit, or whether the man was hit, by Bob, with a stick.
Inflective	A report showing what the product of our last marketing campaign for sales of our accounting software product in the last month was. Ambiguity here derives from the use of the word "product" with two different meanings in the one information request.
Pragmatic	A report of all the clients for a department. The ambiguity here is that the department has not been specified. Information necessary to clearly understand the message is omitted. It would be legitimate to prepare a report for any department. Further information is needed to resolve this actual ambiguity.
Extraneous	A report of all clients (and their names and addresses only) for the Tax and Business Services department. Some of those clients are our biggest earners, you know. The last sentence is extraneous. Unlike pragmatic ambiguity, the sentence contains information that is redundant, uninformative, or not necessary to derive the statement's message. Noise exists in the communication. More words are used than are necessary to make the statement.
Emphatic	A report of our good clients. Ambiguity here could derive from the lack of ability to provide emphasis of the words in its written form. Depending on the emphasis used, "good clients" could be legitimately interpreted to be clients that pay on time, clients that have the most dollar-value sales, or even, with the correct ironic emphasis on the spoken word, our worst —those that do not pay.
Suggestive	A report of the clients of this accounting practice that have lodged taxation returns in the past five years in accordance with the requirements of the Australian Taxation Office. The request for information is quite clear until the phrase "in accordance with the requirements of the Australian Taxation Office." By definition, all taxation returns should be lodged in accordance with these requirements. The extra phrase introduces suggestive ambiguity into the information request by suggesting that the report will not necessarily consist of all taxation clients.

For each information request, participants received either a clear formulation or an ambiguous formulation of the request. The formulation of successive requests alternated between the clear and ambiguous versions. Group A participants received an ambiguous formulation first, and group B participants, a clear formulation first. The required query was identical for both formulations of the same information request. For example, the clear statement of one request and its ambiguous restatement were:

Clear request	List item maker, item number, item name, and (sum of quantity accepted)/(sum of quantity shipped) grouped by item maker, item number, and item name.
Ambiguous request	Report the suppliers, the items they supply, and the ratio of the sum of quantity accepted to the sum of quantity shipped for each supplier's items. The report should help us identify shippers who supply poor quality packaging and bottles.

After eliminating incomplete responses, examiners independently corrected participants' responses according to model queries using counting forms. Each discrete alteration (addition or deletion of a query component) counted as one error. The corrected response that determined the total error count was the response that required the fewest changes to the participant' response for producing the required result. The examiners compared their independent assessments to ensure that all errors had been found and corrected and that the proposed formulations or corrected formulations produced the correct result.

CURRENT STATUS

Table 2 summarizes comparative statistics for queries for 95 participants.

Table 2. Comparative Statistics for Participant Responses Grouped by Information Request (R) and Treatment (T: a = ambiguous, c = clear).

R	T	Halstead Complex-ity	Group	Number of partici-pants	Number of attempts		Confidence		Duration		Total errors	
					Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
1	a	1.6927	0 A	46	5.67	5.56	5.65	1.77	16.22	10.46	3.02	5.02
1	c	1.6927	B	49	3.82	4.13	6.39	1.15	8.88	5.28	0.29	0.84
2	a	5.4186	B	49	4.16	4.13	6.39	1.13	10.00	8.78	0.37	2.02
2	c	5.4186	A	46	5.00	4.85	6.22	1.11	10.25	7.67	0.72	3.05
3	a	6.8908	A	46	6.96	5.23	6.04	1.41	11.89	7.31	2.43	4.47
3	c	6.8908	B	49	4.76	4.49	6.76	0.52	8.64	5.16	0.20	0.50
4	a	4.4697	B	49	10.47	8.99	5.24	2.15	19.91	13.72	2.73	4.72
4	c	4.4697	A	44	7.16	8.27	6.14	1.58	11.44	8.54	0.75	2.30
5	a	12.1067	A	43	11.72	8.01	5.40	1.75	22.38	12.84	7.56	12.73
5	c	12.1067	B	46	11.33	11.85	5.13	2.28	20.30	14.5	4.28	5.74
6	a	13.2896	B	31	12.03	9.87	4.55	2.22	28.11	14.99	9.16	9.76
6	c	13.2896	A	36	7.39	4.07	5.92	1.48	14.24	6.19	3.72	6.09
7	a	16.0076	A	23	11.83	7.99	5.13	1.46	24.59	10.33	7.00	7.39
7	c	16.0076	B	19	7.00	4.26	5.74	1.59	16.75	6.68	4.63	6.27
8	a	16.2683	B	14	8.50	6.70	5.07	2.13	14.58	5.84	15.64	14.65
8	c	16.2683	A	16	5.25	4.31	5.19	2.04	10.94	6.27	4.19	4.85
9	a	23.2461	A	4	10.25	5.91	4.75	2.06	22.29	9.01	13.75	13.87
9	c	23.2461	B	4	10.75	5.85	5.25	1.50	20.60	2.74	8.50	7.37
10	a	18.7026	B	2	7.00	5.66	4.50	2.12	9.46	3.95	11.50	10.61
10	c	18.7026	A	1	5.00	-	4.00	-	8.53	-	23.00	-
11	a	22.4000	A	1	4.00	-	5.00	-	7.12	-	12.00	-
11	c	22.4000	B	1	3.00	-	7.00	-	5.38	-	0.00	-
12	a	23.6027	A	1	9.00	-	6.00	-	18.15	-	3.00	-
12	c	23.6027	B	0	-	-	-	-	-	-	-	-

Table 3 provides initial results from regressing ambiguity and complexity (Halstead 1977) on total errors (square root of the number of errors), duration, and confidence measures of user query performance. All general relationships are strongly supported (positive for H1a and H1b, negative for H1c).

Table 4 provides initial results for regressing each ambiguity type on total errors (square root of the number of errors), duration, and confidence measures of user query performance. These results provide insight into which types of ambiguities might be most problematic in end-user querying.

Table 3. Results for the General Ambiguity Regression Model

Source (n = 620)	**DF**	**Mean square**	**F-value**	**Pr > T (2-tailed)**	**Parameter estimate**	**R^2**
Model: SQRT(Total errors)	3	115.59	65.05	0.0001		0.2421
Error	611	1.78				
Ambiguity (H1a)	1	73.86	41.57	0.0001	0.6932	
Complexity	1	271.59	152.84	0.0001	0.1294	
GPA	1	13.18	7.42	0.0066	-0.1781	
Model: Duration	3	3548.09	32.45	0.0001		0.1376
Error	610	109.35				
Ambiguity (H1b)	1	4536.18	41.48	0.0001	5.4374	
Complexity	1	5439.90	49.75	0.0001	0.5791	
GPA	1	1347.95	12.33	0.0005	-1.8013	
Model: Confidence	3	36.33	13.18	0.0001		0.0608
Error	611	2.75				
Ambiguity (H1c)	1	36.28	13.16	0.0003	-0.4858	
Complexity	1	72.37	26.36	0.0001	-0.0669	
GPA	1	0.56	0.20	0.6512	0.0368	

DESCRIPTION OF PRESENTATION

At the presentation, the authors will share more complete results of query performance and characterize the implications for practice. Specifically, the presentation will outline strategies for countering the ambiguity-generating influences of extensive use of e-mail to transmit information requests without benefit of other communication channels and of high personnel turnover in work teams that prompt insufficient understanding of organizational contexts.

References

Almuallim, H., Akiba, Y., Yamazaki, T., and Kaneda, S. "Learning Verb Translation Rules from Ambiguous Examples and a Large Semantic Hierarchy," *Computational Learning Theory and Natural Learning Systems* (4), 1997, pp. 323-336.

Borthick, A. F., Bowen, P. L., Jones, D. R., and Tse, M. H. K. "The Effects of Information Request Ambiguity and Construct Incongruence on Query Development," *Decision Support Systems* (32:1), 2001, pp. 3-25.

Halstead, M. H. *Elements of Software Science*, Elsevier North-Holland Inc., Amsterdam, 1977.

Jih, W. J. K., Bradbard, D. A., Snyder, C. A., and Thompson, N. G. A. "The Effects of Relational and Entity-Relationship Data Models on Query Performance of End Users," *International Journal of Man-Machine Studies* (31), 1989, pp. 257-267.

Reisner, P. "Use of Psychological Experimentation as an Aid to Development of a Query Language," *IEEE Transactions on Software Engineering* (SE3:3), 1977, pp. 218-299.

Walton, D. *Fallacies Arising from Ambiguity,* Kluwer Academic Publishers, Dordrecht, 1996.

Table 4. Regression Analysis Results By Ambiguity Type

Source (n = 620)	**DF**	**Mean square**	**F-value**	**Pr > T (2-tailed)**	**Parameter estimate**	**R^2**
Model: SQRT(Total errors)	9	45.87	27.21	0.0001		0.2882
Error	605	1.68				
Lexical (H2a)	1	0.95	0.57	0.4520	0.2332	
Syntactical (H3a)	1	33.52	19.89	0.0001	0.6749	
Inflective (H4a)	1	4.80	2.85	0.0920	0.9219	
Pragmatic (H5a)	1	18.81	11.16	0.0009	0.9259	
Extraneous (H6a)	1	18.51	10.98	0.0010	0.6570	
Emphatic (H7a)	1	22.37	13.27	0.0003	-1.0478	
Suggestive (H8a)	1	1.44	0.85	0.3559	-0.4910	
Complexity	1	169.40	100.51	0.0001	0.1198	
GPA	1	17.40	10.32	0.0014	-0.2059	
Model: Duration	9	1643.43	15.87	0.0001		0.1912
Error	604	103.58				
Lexical (H2b)	1	458.89	4.43	0.0357	5.1177	
Syntactical (H3b)	1	792.96	7.66	0.0058	3.2823	
Inflective (H4b)	1	0.00	0.00	0.9993	0.0036	
Pragmatic (H5b)	1	1.10	0.01	0.9178	-0.2243	
Extraneous (H6b)	1	2480.02	23.94	0.0001	7.6056	
Emphatic (H7b)	1	132.74	1.28	0.2581	-2.5557	
Suggestive (H8b)	1	86.33	0.83	0.3616	3.8030	
Complexity	1	2329.07	22.49	0.0001	0.4444	
GPA	1	1331.68	12.86	0.0004	-1.8008	
Model: Confidence	9	17.50	6.47	0.0001		0.0878
Error	605	2.70				
Lexical (H2c)	1	0.77	0.29	0.5931	-0.2099	
Syntactical (H3c)	1	2.58	0.95	0.3293	-0.1871	
Inflective (H4c)	1	0.01	0.00	0.9654	0.0300	
Pragmatic (H5c)	1	4.38	1.62	0.2039	-0.4465	
Extraneous (H6c)	1	35.75	13.22	0.0003	-0.9131	
Emphatic (H7c)	1	8.43	3.12	0.0779	0.6434	
Suggestive (H8c)	1	0.15	0.06	0.8115	-0.1631	
Complexity	1	48.66	17.99	0.0001	-0.0642	
GPA	1	0.52	0.19	0.6605	0.0356	