Introduction

The evaluation of experimental, as opposed to operational, information retrieval systems first requires the establishment of an environment. In real life the minimum requirement for an IR system is a set of documents and one or more users, that is individuals for whom the document set can meet an information requirement. While it is relatively easy to obtain a set of documents that can be used in an experimental system, it is in practice, if not in theory, impossible to obtain a genuine group of users. There are obvious reasons for this; economically it is not possible to have a large and comprehensive set of documents, therefore potential users cannot be expected to become genuine users. The best that can be expected is to obtain a set of potential users who will simulate as closely as possible the actions which they would carry out in an operational system. These actions mainly consist of the formulating and stating of search questions, and judgements concerning the relevance of documents presented to them.

The simplest method of obtaining questions and relevance judgements is the "source - document question" technique originally used at Cranfield in 1953 (Ref. 1), but best known as the result of its use in Cranfield I (Ref. 2). The main developments and variations of this technique can be set out as follows:

Types of search questions

1. An actual question that is put to an information retrieval system and searched at the time it is required.

2. An actual question that has been put to an IR system. In other words, questions that have been used previously, either with the system being tested or some other system.

3. A prepared question, that is a question which has been composed specifically for the purpose of the test and is not a question which meets an actual need of the questioner. Such prepared questions may or may not be based on a particular document or documents.

Method of Relevance Assessment

I By the questioner
II By the concensus of opinion of a group of people
III By an individual, not the questioner
IV By matching the indexing with the search programme.

Type of Individual(s) Involved

A User of a system
B Scientific or technical staff, not users of the system
C Librarians or other information staff.

If Type of Question is put against Method of Relevance Assessment, the various posibilities can be shown.

Method of Relevance Assessment

Type of Question		I	II	III	IV
	1	A / A	A / BC	A / BC	A / -
	2	AB / AB	AB / BC	AB / BC	AB / -
	3	ABC / ABC	ABC / ABC	ABC / ABC	ABC / -

In the chart, the upper half of each box represents the type of person asking the question, the lower half represents the type of person making the relevance assessment.

In Cranfield II (Ref. 3) the test set of questions was obtained by asking scientists to state questions which had been put to an IR system and to state which documents had been found to be relevant to these questions. From the table given above the question and assessment would be graded at (2B) (IB), which was considered to be as close as it was possible to get to the situation which exists in an operational environment, namely (1A)(IA). The test set of documents was largely made up of the documents which had been stated to be relevant to the set of test questions.

When the environment has been fixed, experimental tests must be so controlled that the effect can be measured of changing a single variable. Conversely, there is no point in carrying out a test in an artificial environment in which none of the variables is changed. In Cranfield II the main variable being investigated was the index language and 33 index languages were tested. For this to be done, all other variables had to be held constant; one set of indexing decisions was used throughout and the different index languages were applied to this basic set of indexing decisions. However, the test was so designed that it was possible to investigate other variables such as the level of the exhaustivity of indexing, but it was index languages which were the main consideration.

The use of the measure "normalised recall" based on an adaptation of the measure originally used by Professor Salton (Ref. 4), permitted an order of merit to be established for the 33 index languages, and this is given in Figure I. Based on this measure, the results appeared to show that single terms in natural language, with only the minimum of control, performed better than any other method. Because this was completely unexpected, in fact the contrary of the original hypothesis, considerable effort was put into establishing whether the results could have been distorted by any factor or factors of the environment or by the measures used. In most areas it was possible to advance reasoned arguments, supported by results from other tests, to show that the environment could not have been responsible for the unexpected results; the only area for which at that time no experimental evidence existed was in relation to the relevance decisions. With Cranfield I it was difficult to argue that the use of source document questions had not affected the comparative results, but the increased control which had been introduced into Cranfield II made it seem improbable that the relevance decisions had played a significant part in determining the order of merit of the index languages. However, a suspicion remained that this might be the cause, so a proposal was made to investigate this matter; this report is an account of the resulting project which was supported by a grant from the Office of Scientific and Technical Information of the Department of Science.

Design of the Test

In Cranfield II, the main series of tests had been carried out on subsets of the original sets of documents and questions; these subsets, consisting of 200 documents and 42 questions (as given in Appendix I) were used in the present test. For each question there was a known group of relevant documents, varying in number from a minimum of 1 to a maximum of 12, with an average of 4.7 per question. The relevance of the documents had been determined in scale of 1 - 5 which was interpreted as follows:

(1) References which are a complete answer to the question. Presumably this would only apply for supplementary questions, since if they applied to the main question there would have been no necessity for the research to be done.

(2) References of a high degree of relevance, the lack of which either would have made the research impracticable or would have resulted in a considerable amount of extra work.

(3) References which were useful, either as general background to the work or as suggesting methods of tackling certain aspects of the work

(4) References of minimum interest, for example, those that have been included from an historical viewpoint.

(5) References of no interest.

ORDER	NORMALISED RECALL		INDEXING LANGUAGE
1	65.82	I-3	Single terms. Word forms
x 2	65.23	I-2	Single terms. Synonyms
x 3	65.00	I-1	Single terms. Natural Language
x 4	64.47	I-6	Single terms. Synonyms, word forms, quasi-synonyms
x 5	64.41	I-8	Single terms. Hierarchy second stage
x 6	64.05	I-7	Single terms. Hierarchy first stage
7=	63.05	I-5	Single terms. Synonyms. Quasi-synonyms
7=	63.05	II-11	Simple concepts. Hierarchical and alphabetical selection
9	62.88	II-10	Simple concepts. Alphabetical second stage selection
x 10=	61.76	III-1	Controlled terms. Basic terms
x 10=	61.76	III-2	Controlled terms. Narrower terms
12	61.17	I-9	Single terms. Hierarchy third stage
x 13	60.94	IV-3	Abstracts. Natural language
x 14	60.82	IV-4	Abstracts. Word forms
x 15	60.11	III-3	Controlled terms. Broader terms
x 16	59.76	IV-2	Titles. Word forms
x 17	59.70	III-4	Controlled terms. Related terms
x 18	59.58	III-5	Controlled terms. Narrower and broader terms
x 19	59.17	III-6	Controlled terms. Narrower, broader and related terms
x 20	58.94	IV-1	Titles. Natural language
x 21	57.41	II-15	Simple concepts. Complete combination
22	57.11	II-9	Simple concepts. Alphabetical first stage selection
x 23	55.88	II-13	Simple concepts. Complete species and superordinate
24	55.76	II-8	Simple concepts. Hierarchical selection
x 25	55.41	II-12	Simple concepts. Complete species
26	55.05	II-5	Simple concepts. Selected species and superordinate
27	53.88	II-7	Simple concepts. Selected coordinate and collateral
28	53.52	II-3	Simple concepts. Selected species
x 29	52.47	II-14	Simple concepts. Complete collateral
30	52.05	II-4	Simple concepts. Superordinate
31	51.82	II-6	Simple concepts. Selected coordinate
32	47.41	II-2	Simple concepts. Synonyms
33	44.64	II-1	Simple concepts. Natural language

FIGURE 1. Order of Effectiveness based on normalised recall for 33 Cranfield Index Languages (^{x}Index languages used in present test)

In the project it was proposed to have relevance decisions made by three other people. It being a well-established fact that there is a significant variation (up to 10%) in relevance decisions when these are based on titles rather than on full text, it was considered essential that full text should be used. This decision affected the scale of the test, for it was impracticable to contemplate having staff working on this project full-time. Part-time staff might be expected to do, on a regular basis, about four hours each week, and preliminary tests showed that in this time it was possible to reach studied decisions of some 20 fringe documents. By the description "fringe documents" is implied documents which are at least on the border line of relevance. Clearly to reject as non-relevant, in relation to a question on aerodynamics, 20 documents dealing with Chinese vases would take only a minute; although in the main project all the documents in the test collection dealt with aerodynamics, yet for the trained aerodynamicist many could immediately have been rejected as non-relevant in relation to a specific question.

Two methods of obtaining a sub-set of 200 or so documents were considered; one method was to take all the documents judged relevant by the original questioners, add a number of non-relevant documents retrieved at high coordination levels and also non-relevant documents having a relatively high bibliographic coupling with known relevant documents. The alternative method would be for the relevance judge to read through the titles of the 200 documents in the test collection in relation to a given question and select about 20 that looked as though they might be relevant. This latter method was tried in preliminary tests, but not unexpectedly it was found that on the basis of titles, the assessors were rejecting documents that were relevant and which they would have accepted as relevant on the basis of the complete document. For this reason, the decision was taken to use the former method.

With 42 questions to be used, it was hoped that the first phase of the work would be completed within a year. The three persons who agreed to take part in the tests were Mr. T. Bateman, Senior Aerodynamicist at the Aircraft Research Association, Mr. E. J. MacAdam, formerly Librarian of the Aircraft Research Association, and Mr. G. Scott, a Research Fellow in the Department of Aerodynamics, at the College of Aeronautics.

Test Procedure

The first requirement was to prepare sets of documents to be assessed for relevance for each of the questions. This was done on the basis already mentioned, except that for each question two or three additional documents, taken at random from the complete collection, were added to the set. Over the range of 42 questions, the number of documents originally considered relevant varied from one to twelve for different questions; this variation was reflected in the test sets, which ranged from thirteen to twenty-nine, with an average of 19 documents per question. The document sets are given in Appendix II.

To Mr. Scott.　　　　　　Date 26-3-68

Please find enclosed herewith the documents relating to question 118

Do the discrepancies among current analysis of the vorticity effect on stagnation-point heat transfer result primarily from the differences in the viscosity temperature law assumed

The following documents are included in this set

1324 - 1378 - 1436 - 1437 - 1509 - 1575 - 1576 - 1666 - 1667 - 1670 - 1695 - 1707 - 1779 - 1880 - 1964 - 1978 - 2099 2100 - 2274 - 2319 - 2391.

The relevance decisions should be made in accordance with the following definitions:

1. Documents which are a complete answer to the question.

2. Documents of a high degree of relevance.

3. Documents which might be useful, either as general background, work or as suggesting methods of tackling certain aspects of the work.

4. Documents of minimum relevance.

5. Documents of no relevance.

FIGURE 2. Question sheet for Q. 118 for Scott.

Copies of the documents for a given question set were collected and a relevance assessment sheet attached to each document (Fig. 2); these were then sent to the assessor with a question sheet (Fig. 3), giving particulars of the search question and the documents. The assessors made their relevance judgements and in some cases added comments before returning the documents and assessment sheets. From these sheets the relevance decisions were extracted and recorded as in Fig. 4. (see also Appendix III).

Although in Cranfield II 29 index languages had been tested, it was not considered necessary to check every language in this test, and 15 index languages were selected. In addition to the above group of index languages, all of which were based on the same set of indexing decisions, Cranfield II had also tested the effect of substituting for the index entries the terms in titles or abstracts; these variations in indexing had been tested with single term natural language, and single term word forms, and provided a further four sets of results. In total, therefore, there were nineteen index languages or indexing variations to be considered as indicated in Figure 1.

As all the test data from Cranfield II was still available, it was a relatively straightforward, although somewhat tedious process, to estimate the results based on the new relevance decisions. As an example, we show the results for Question 118, using the new set of relevance decisions as made by Scott and MacAdam (Fig. 5). In Cranfield II, five documents (1324, 1378, 1666, 1667, and 1670) were considered relevant, and the coordination levels at which these documents were retrieved is shown in the first column, together with the number of non-relevant documents retrieved. Scott was in agreement concerning the relevance of four of these documents, but rejected 1378 as non-relevant. Whatever documents are judged relevant or non-relevant, the total number of documents retrieved at any coordination level must be the same, and therefore the only difference will lie in the proportion of relevant and non-relevant. With index language I. 1, document 1378 was retrieved at a coordination level of 3, so at this stage there is a change as compared to the figures in the first column, and this continues at the lower coordination level. On the other hand, MacAdam accepted as relevant not only the original set, but a further ten documents, and the effect of this on the scoring can be seen in the third column.

This exercise was repeated for all 42 questions, for the 19 index languages, and for each of the three assessors; part of an index language result sheet is shown in Fig. 6 for index language I. 1 in relation to the decisions by Scott. From such sheets, using the method considered at length in Chapter 6 of Ref. 3 the normalised recall ratio was obtained for each of the 57 cases. Briefly, the measure is a simplification of the computer-calculated measure originally devised by Salton. A simulated ranking is given to all the documents and 17 cut-off points for document

ASSESSOR Mr. Scott

CRANFIELD PROJECT ON RELEVANCE DECISIONS

QUESTION No. 118

DOCUMENT No. 1670

RELEVANCE DECISION

1	2	3	4	5
	✓			

COMMENTS

This document is considered highly relevant because it deals specifically with the discrepances refered to in the question.

FIGURE. 3. Example of document assessment sheet.

Question 118 Document	Cranfield	Scott	MacAdam	Bateman
1324	3	3	2-3	3
1378	3	5	3	3
1436	5	5	4	2
1437	5	5	4	3
1509	5	5	4	4
1575	5	5	5	5
1576	5	5	4	3
1666	3	3	3	2
1667	2	3	3	2
1670	3	2	2	1
1695	5	5	5	5
1707	5	5	4	4
1779	5	5	5	5
1880	5	5	5	5
1964	5	5	5	5
1978	5	5	4	4
2099	5	5	4	4
2100	5	5	4	4
2274	5	5	4	4
2319	5	5	4	4
2391	5	5	2-3	2

FIGURE 4. Relevance decision for Question 118 by the three judges.

Coordination Level	Cranfield II Rel.	Cranfield II N. R.	Scott Rel.	Scott N. R.	MacAdam Rel.	MacAdam N. R.
6+	0	1	0	1	1	0
5+	3	10	3	10	9	4
4+	3	17	3	17	12	8
3+	5	29	4	30	14	20
2+	5	49	4	50	15	39
1+	5	123	4	124	15	113

FIGURE 5 Comparative results for Q118 with Index Language I. 1.

		Co-ordination Level 1 +		2 +		3 +		4 +		5 +		6 +		7 +	
Question	No. of Relevant Document	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR
170	1	1	110	1	45	1	18	1	6	1	1				
181	2	2	90	2	42	1	7								
182	3	3	163	1	47	1	5								
189	6	1	65	1	11	0	1								
190	6	5	164	5	46	4	11	3	0						
223	2	2	148	2	75	2	38	2	19	2	3	2	1	2	0
224	2	2	50	2	67	0	29	0	3						
225	4	4	160	4	91	4	43	2	17	0	5				
226	9	9	58	6	17	5	1	4	1	2	0				
227	2	2	83	2	35	2	8	2	3	1	0	1	0		
239	5	5	44	2	0	1	0								
250	8	8	162	8	54	8	25	8	7	5	4	3			
261	3	3	132	3	35	3	14	3	6	3	1	3	1	2	1
264	2	2	104	2	29	2	5	2	1	1	0	1	0	1	0

FIGURE 6. Results sheet for Index Language I. 1 based on relevance decisions by Scott.

output are selected. The recall ratio is calculated for each of these points, these are then summed, and when divided by 17 produce the normalised recall. Fig. 7 is an illustration of this in relation to index language I. 1 for the three assessors. It will be noted that, in every case, the resulting final figure varies; this is due to the differing numbers of relevant documents and is in no way indicative of better or worse performance. The comparison that has to be made is not between the figures obtained for different sets of relevant documents, but between the different index languages for the same set of relevant documents.

Main Results

The normalised recall obtained for each assessor for all nineteen index languages is given in Fig. 8, together with the original results obtained in Cranfield II. The purpose of this test was to find whether these new sets of relevance decisions made any significant difference in the order of merit, as determined by the normalised recall, of the index languages. The rank order of each language is given in Figure 9, and in Figure 10 the index languages are rearranged in order of their ranking. Visually it can be seen that there is a strong correlation between the original ranking and each new set of rankings, but to determine the significance of these results, the Spearman rank-correlation coefficient is used. This is a function of the sum of the squares of the differences of the two rankings for each observation and the number of observations, so that

$$r_s = 1 - \frac{6 \Sigma d_i^2}{n(n^2 - 1)}$$

where r_s = Spearman rank-correlation coefficient

d_i = difference between the rankings of the ith observation

n = number of observations.

The maximum value of r_s that would be expected by chance at the level of 0.01 with 19 observations is 0.538.

The rank-correlation between the various sets of relevance decisions is calculated from Figure 10 and is presented in Figure 11.

The figures appear to confirm the original hypothesis, namely that the relevance decisions did not significantly affect the comparative results of Cranfield II. The rank correlation never falls below 0.92; where there are comparatively large changes in the ranking, as with index language III. 5 which rises from rank 13 with the original results to rank 8 for Scott, the actual difference in the normalised recall is small and an increase of 1.4% would have raised it to the eighth position in the original test. In Ref. 3 we suggested that it might be unwise to consider as

Document Output Cut off	Scott	Bateman	MacAdam
	% Recall	% Recall	% Recall
1	12.22	6.53	6.62
2	21.10	12.65	12.65
3	31.10	16.73	17.26
4	37.77	22.04	22.69
5	40.54	27.14	27.10
6-7	48.32	33.67	34.93
8-10	57.21	42.24	45.27
11-15	64.44	52.85	53.01
16-20	68.32	59.18	61.44
21-30	76.10	69.18	71.28
31-50	83.88	77.75	79.51
51-75	86.66	82.24	83.53
76-100	90.54	88.30	86.34
101-125	93.87	89.38	90.16
126-150	96.66	93.67	93.97
151-175	100.00	98.36	98.79
176-200	100.00	100.00	100.00
Normalised Recall	65.21	56.99	57.75

FIGURE 7 Normalised recall for three sets of relevance decisions for Index Language I.1

	Cranfield II	Scott	Bateman	MacAdam
I. 1	65.00	65.21	56.99	57.75
I. 2	65.23	65.46	57.28	58.16
I. 6	64.47	65.91	57.78	57.98
I. 7	64.45	65.52	57.70	57.99
I. 8	64.41	63.12	55.48	55.79
II. 12	55.41	56.39	40.82	40.20
II. 13	55.88	55.74	43.75	42.56
II. 14	52.47	52.50	44.66	43.50
II. 15	57.41	58.06	49.13	49.10
III. 1	61.76	61.52	49.52	50.49
III. 2	61.76	61.49	49.24	50.50
III. 3	60.11	59.89	48.57	49.74
III. 4	59.70	59.66	48.78	49.52
III. 5	59.58	61.72	48.71	49.58
III. 6	59.17	60.96	48.99	49.66
IV. 1	58.94	60.22	44.92	45.14
IV. 2	59.76	61.23	45.57	45.40
IV. 3	60.94	62.96	52.38	52.96
IV. 4	60.82	62.40	52.15	52.71

FIGURE 8 Normalised recall ratios for four sets of relevance decisions

	Cranfield II	Scott	Bateman	MacAdam
I. 1	2	4	4	4
I. 2	1	3	3	1
I. 6	3	1	1	3
I. 7	4	2	2	2
I. 8	5	5	5	5
II. 12	18	17	19	19
II. 13	17	18	18	18
II. 14	19	19	17	17
II. 15	16	16	14	14
III. 1	6	9	8	9
III. 2	7	10	9	8
III. 3	10	14	13	10
III. 4	12	15	11	13
III. 5	13	8	12	12
III. 6	14	12	10	11
IV. 1	15	13	16	16
IV. 2	11	11	15	15
IV. 3	8	6	6	6
IV. 4	9	7	7	7

FIGURE 9 Rank order of index languages

Rank	Cranfield II	Scott	Bateman	MacAdam
1	I. 2	I. 6	I. 6	I. 2
2	I. 1	I. 7	I. 7	I. 7
3	I. 6	I. 2	I. 2	I. 6
4	I. 7	I. 1	I. 1	I. 1
5	I. 8	I. 8	I. 8	I. 5
6	III. 1	IV. 3	IV. 3	IV.3
7	III. 2	IV.4	IV. 4	IV.4
8	IV.3	III. 5	III. 1	III. 2
9	IV.4	III. 1	III. 2	III. 1
10	III. 3	III. 2	III. 6	III. 3
11	IV.2	IV.2	III. 4	III. 6
12	III. 4	III. 6	III. 5	III. 5
13	III. 5	IV.1	III. 3	III. 4
14	III. 6	III. 3	II. 15	II. 15
15	IV.1	III. 4	IV. 2	IV.2
16	II. 15	II. 15	IV. 1	IV.1
17	II. 13	II. 12	II. 14	II. 14
18	II. 12	II. 13	II. 13	II. 13
19	II. 14	II. 14	II. 12	II. 12

FIGURE 10 Comparison of rank order for four sets of relevance decisions

	Cranfield	Scott	Bateman	MacAdam
Cranfield	-	0. 921	0. 925	0. 944
Scott	0. 921	-	0. 933	0. 925
Bateman	0. 925	0. 933	-	0. 977
MacAdam	0. 944	0. 925	0. 977	-

FIGURE 11 Rank-correlation coefficients.

significant a difference in the normalised recall ratio of less than 3%, but in that the greatest difference between any two sets of figures as shown by this test is 1.4%, it would be reasonable to suggest that 2% could be considered significant.

The results obtained in this test have, in fact, been supported by a similar test undertaken by Lesk and Salton (Ref. 4) in connection with the Smart project. In this work, a collection of 1268 abstracts in the field of documentation was used. Eight different persons (librarians or library students) were asked to generate six requests that might actually be put to such a collection. When these had been received, each person was sent a copy of the complete set of abstracts, and working to definite instructions, was asked to assess the relevance of each document with respect to each of his six queries. Then a second set of independent relevance judgements was obtained by asking each person in the test group to judge for relevance six additional queries originated by other people.

The most interesting aspect of the Smart test was that the relevance judges only had an average consistency of 30%. While the authors of the questions selected 853 documents as relevant to their own questions, only 713 documents were judged relevant when the assessment was of questions originated by other people. In total, 1260 documents were considered relevant, but only 366 were common to the two groups. This consistency of 30% is very similar to the consistency found in tests of indexers (Ref. 5), and compares, for instance, with the very high consistency of 79% achieved in the Cranfield test by Scott with the original decisions of the questioners. This high consistency may be partly due to the use of full text documents rather than abstracts.

Lesk and Salton tested three index languages, and consistently found that the thesaurus was better than word stems, which was in turn better than word forms. Although the test was on a smaller scale than the Cranfield work, there seem no grounds for arguing against their conclusion that "there appears to be no reason to reject previously published evaluation results for manual or automatic searches because of uncertainties in the computation of the performance measures".

The results of this test can only lead to the same conclusion. In the light of the considerable amount of criticism concerning relevance decisions which has been made over the past decade, it is desirable to make an attempt to explain the results. Some of the earliest criticisms came from Fairthorne who suggested that relevance refers to a group or type of request, rather than to an individual user, and that therefore individual judgements should give way to the views of a group of users. Taube (Ref. 6) attacked the whole idea of relevance and expressed the view that recall and precision could not be accepted as valid measures of I.R. systems. O'Connor, in a continuing series of papers (Ref. 7) has argued that relevance can mean many different things to the same person at different times, or in different situations; because of this, it is not possible to speak of relevance without defining in detail the particular circumstances.

These and other comments led to the setting-up of two investigations into relevance, supported by grants from the National Science Foundation. Cuadra and Katter (Ref. 8) and Rees and Schultz (Ref. 9) both attempted to analyse the effect of the variables involved in relevance judgements. While both these tests were, in their ways, of interest, neither had any real connection with the problems of relevance decisions. The fault was that the attempts to find how people arrived at relevance decisions in real life were carried out in a completely artificial environment. For example, in the S.D.C. test (Ref. 8) the subjects (psychology students) were presented with nine abstracts and eight question statements. They were then given the following instruction:

> "You are to imagine that you are acting as judging agent for a person who is strongly concerned about the problem of increasing the precision of use of terminology in science. You are aware that in making each relevance rating you are demonstrating exactly what each term in your requirement statement means to you (or does not mean to you). You appreciate the fact that all terminology is arbitrary, and that therefore the important thing is not 'picking the right term', but rather, the important thing is that everyone should try to use the same term. You will try to judge the relevance of articles accordingly".

This exercise was repeated 14 times with different sets of instructions, each of which required the relevance judgement to be biased by a particular viewpoint, each of which tried to simulate a real-life situation, but all baulked by the fact that it was a simulation. In the final report the authors do not appear to have appreciated the artificiality of the test-environment and the report contains many statements that could only apply to a real-life situation, and for which the project produced absolutely no evidence. However, in the matter of artificial relevance judgements, they make the claim that relevance scores are likely to be artefacts of particular experimental instructions and conditions, and that therefore while "this conclusion does not invalidate experiments in which a given group of judges makes relevance appraisals for a specific system, it does call into question any comparative evaluations (between systems and sub-systems) in which the attitude of the judges about the intended use of the materials was not considered and controlled, either experimentally or statistically".

This statement, which is clearly directed to the Cranfield and Smart projects, draws false conclusions from the test results, and shows a complete misunderstanding of operational situations. From their statements, the authors appear to think that scientists are significantly influenced by subconscious motives in making a decision as to whether a given document is or is not relevant to the problems with which they are concerned. One can consider that if every user of a given system approached the analysis of his output in one specific way, as for instance, a concern with terminology as in the example above, one would expect different relevance judgements than if everybody approached it from another fixed viewpoint of, say, methodological interest. However, anyone with practical experience of operational systems will know that users do not fall into any one such category and, in general, information retrieval systems are not designed to serve only people having one particular quirk or bias. This is one reason why in the Cranfield projects we have deliberately been vague in our instructions to the relevance judges; apart from interpreting the different levels of relevance, we have left it to the scientists involved in the decisions to make these based on their normal approach. Had we tried to introduce the strict controls advocated by Cuadra and Katter, the relevance decisions might have been completely distorted from what one would reasonably expect to find in a real-life situation. No doubt, amongst the 200 relevance judges in Cranfield II there were some who were more concerned than the average with a particular aspect, such as methodology or terminology, but taken together, we would argue that they were representative of the user group of an operational service covering aerodynamics, and for the large majority, their interest in the subject content of the documents would be sufficient to outweigh their personal idiosyncracies concerning presentation.

A major reason for undertaking the investigation covered in this report was that the results of Cranfield II were so unexpected that it was essential to check every possible source of error. However, other tests, such as that by Aitchison, (Ref.11) largely confirmed the results of Cranfield II, and with greater understanding of the workings of information retrieval systems, it is quite obvious that a system using the natural language of the documents in the collection and the natural language of question statements can never - other things being equal - have a worse performance than a system using any form of controlled language. It may not be significantly better, nor may it economically be so efficient, but in relation to performance, it can never be improved.

We can therefore claim that, quite apart from the results of this test and that by Salton, the mere fact that Cranfield II gave the correct results can be taken as positive proof that the methodology - including in particular the relevance decisions - as used in Cranfield II was also correct.

The Effect of Random Relevance

As an exercise, it was decided that an attempt would be made to find the effect of random changes in the sets of relevance documents. For this test, twenty questions, each of which had a minimum of four and a maximum of eight relevant documents were selected, the question numbers being as follows:

Question No.	No. of relevant documents
100	4
116	6
118	5
119	6
122	5
123	4
130	4
132	4
136	6
137	6
147	5
148	4
167	4
224	5
250	8
261	4
266	5
268	5
274	5
323	5

It will be noted that there were exactly 100 relevant documents for this set of twenty questions.

The test was carried out on six index languages, namely I-1, I-7, III-2, IV-2, II-15, and II-12. The normalised recall ratios for the twenty questions as given above were calculated for these six index languages. The actual figures were lower in each case, indicating that this sub-set of twenty questions had not performed as well as the remaining twenty-two questions, but as is shown below, the rank order of the languages is not affected.

Index Language	Normalised recall on 20 questions	Original rank order (see Fig. 1)	Normalised recall on 42 questions (see Fig. 1)
I-1	61.47	1	65.00
I-7	60.76	6	64.05
III-2	58.54	10	61.76
IV-2	56.62	16	59.76
II-15	54.21	21	57.41
II-12	52.07	25	55.41

It will be seen that not only has the rank order remained the same, but also there is approximately the same difference in the normalised recall ratios for any pair of index languages. The test required the addition of increasing numbers of randomly selected documents to the set of relevant documents for each question and then for the random selection of documents to form a new relevant document set which had the same number of documents as the original set. This can most simply be explained by illustrating the effect with a given question. Question 116 has six known relevant documents, namely 1317, 1574, 1575, 1576, 1578 and 1656. From the whole collection of 200 documents, one document was selected at random; it was, in fact, No. 1783. This document was added to the six relevant documents, from which six were taken at random to form the new set of relevant documents. The effect on this occasion was to substitute this presumably non-relevant document, No. 1783, for the known relevant document No. 1576. At the next stage two randomly selected non-relevant documents were added to the original six relevant documents and then a further random selection was made to obtain a new set of six relevant documents. This procedure was repeated adding four randomly-selected documents and finally adding five such documents. At this final stage the relevant document sets were being selected from the total of 200 documents, equally divided between known relevant documents and randomly-selected - therefore presumably non-relevant - documents.

The effect in relation to Question 116 was as follows: (The substituted documents are shown by an asterisk).

Original Relevant Documents	Amended Set 1	Amended Set 2	Amended Set 3	Amended Set 4
1317	1317	1317	1317	1317
1574	1574	1574	* 1615	* 1443
1575	1575	* 1972	1575	1575
1576	* 1783	1576	* 1705	1576
1578	1578	1578	1578	* 1620
1656	1656	1656	1656	* 2391

As can be seen, with Set 4 there is now the position where the set of "relevant" documents is made up of three documents originally judged relevant, namely 1317, 1575 and 1576, and three documents which have been randomly selected and which are, in fact, not relevant, namely 1443, 1620 and 2391.

There were, of course, variations in this random selection. In one case, with Question 167, Set 4 was made up of four new documents, without a single known relevant document being included. There was no situation where the reverse happened, i.e. the relevant set remained as the original, but with Questions 122 and 268, four of the original documents were included. The total of original relevant documents for the four sets, for all twenty questions is as shown below:

	Set 1	Set 2	Set 3	Set 4
Number of relevant documents	84	75	59	49
Number of presumably non-relevant documents	16	25	41	51

New sets of "relevant" documents having been thus obtained, the results were calculated for the twenty questions and six index languages for each of the four sets. This involved going back to the original records and finding whether the added relevant new documents have been retrieved in the course of the search, a procedure similar to that described earlier in this report. On the basis of the new calculations the rank orders of the six index languages were obtained. These are shown below together with the rank correlation.

Index Language	Original order	Set 1	Set 2	Set 3	Set 4
I-1	1	1	1	3	4
I-7	2	2	3	1	3
III-2	3	4	4	4	1
IV-2	4	3	2	6	6
II-15	5	5	5	2	2
II-12	6	6	6	5	5
Rank correlation		0.943	0.829	0.43	0.20

It will be noted that the rank order holds up reasonably well for Sets 1 and 2, but that by Set 3 there are major changes and with the final Set, the result is approaching zero correlation. To consider the position regarding this final set, there were 49 documents, common to both the original set and to Set 4, and 102 documents appeared in only one set. This gives an overlap between the two sets of approximately 30%, and corresponds closely to the overlap between different relevance judgements which was found in the tests reported by Lesk and Salton in Ref. 4. It is reasonable to ask why, in those circumstances they should have found no significant difference between the index languages which were tested whereas in this case the correlation is low. The reason can be appreciated by the quotation by Salton (Ref. 10).

> "The shape of a typical recall precision graph averaged over many search requests is determined almost entirely by the first few documents retrieved (when the documents are retrieved in decreasing order of the correlation coefficient). Thus, by the time the top ten documents are retrieved, usually the precision will be very low and the recall will already be quite respectable. However, it is precisely for the first few documents, which exhibit the highest

correlation coefficient with the query, where the relevance judgements appear to be practically invariant among different judges. It is for this reason that the recall precision graphs stay the same. For documents retrieved late in the search which rank 100 or 200 or 300, etc. the judgements will be very different among the various assessors, but these different judgements will affect only the lower righthand corner of our recall-precision graph (where the recall is higher than .8 and the precision usually lower than .2)."

The overlap in the Lesk and Salton test was due to varying decisions concerning the documents of doubtful relevance which, being retrieved relatively late in the search, do not significantly change the results. However, in this test, the overlap was determined by a random substitution of documents, with the probability that a highly relevant document would be eliminated as would a document of minimum relevance.

Analysis showed that documents retrieved at a relatively high level were eliminated from the relevent documents set. The normalised recall at various stages shows this quite clearly; originally, for the twenty questions, the normalised recall for index language I-1 was 61.47%. The normalised recall for these questions when only the forty-nine remaining relevant documents are counted was 58.5%. This is a relatively small drop, but it shows that the proportion of documents retrieved at high coordination levels which were eliminated, was rather more than might have been expected, since if it had been exactly proportionate, the normalised recall would have remained the same. With Set 4, the normalised recall dropped sharply to 41.7%, showing the effect of complete randomness in the selection of additional documents, for the "relevant" set.

The results of this additional test make clear what might reasonably have been hypothesised, namely that if two sets of relevance judgements, having the same generality number, result in a similar level of performance for any given index language, then there will not be any significant difference in the comparison between different index languages using either set of relevance judgements.

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APPENDIX I

QUESTIONS AND DOCUMENTS USED IN TEST

QUESTIONS

Q79 What are the details of the rigorous kinetic theory of gases. (Chapman-Enskog Theory).

Q100 How much is known about boundary layer flows along non-circular cylinders.

Q116 How significant is the possible pressure of a dissociated free stream with respect to the realization of hypersonic simulation in high enthalpy wind tunnels

Q118 Do the discrepancies among current analyses of the vorticity effect on stagnation-point heat transfer result primarily from the differences in the viscosity - temperature law assumed.

Q119 How far can one trust the linear viscosity - temperature solution assumed in some of the analyses of hypersonic shock layer at low Reynolds number.

Q121 Has anyone explained the kink in the surge line of a multi-stage axial compressor.

Q122 Have any aerodynamic derivatives been measured at hypersonic Mach numbers and comparison been made with theoretical work.

Q123 Are methods of measuring aerodynamic derivatives available which could be adopted for use in short running time facilities.

Q126 What are wind-tunnel corrections for a two-dimensional aerofoil mounted off-centre in a tunnel

Q130 What is the present state of the theory of quasi-conical flows

Q132 What parameters can seriously influence natural transition from laminar to turbulent flow on a model in a wind tunnel.

Q136 How does a satellite orbit contract under the action of air drag in an atmosphere in which the scale height varies with altitude.

Q137 How is the flow at transonic speeds about a delta wing different from that on a closely-related tapered sweptback wing.

Q141 Can methane-air combustion product be used as a hypersonic test medium and predict, within experimental accuracies, the results obtained in air.

Q145 Has anyone investigated the unsteady lift distributions on finite wings in subsonic flow.

Q146 What information is available for dynamic response of airplanes to gusts or blasts in the subsonic regime.

QUESTIONS

Q147 Will forward or apex located controls be effective at low subsonic speeds and how do they compare with conventional trailing-edge flaps.

Q148 Given that an uncontrolled vehicle will tumble as it enters an atmosphere, is it possible to predict when and how it will stop tumbling and its subsequent motion.

Q167 It is not likely that the airforces on a wing of general planform oscillating in transonic flow can be determined by purely analytical methods. Is it possible to determine the airforces on a single particular planform, such as the rectangular one by such method.

Q170 Is there any information on how the addition of a "boat-tail" affects the normal force on the body of various angles of incidence.

Q181 Has any work been done on determining the nature of compressible viscous flow in a straight channel.

Q182 In what areas, other than low density wind tunnel flows, is viscous compressible flow in slender channels a problem.

Q189 Has anyone programmed a pump design method for a high-speed digital computer.

Q190 Has anyone derived simplified pump design equation from the fundamental three-dimensional equations for incompressible nonviscous flow.

Q223 What is the magnitude of second-order wing-body interference at high supersonic Mach number.

Q224 What is the best theoretical method for calculating pressure on the surface of a wing alone.

Q225 How can the effect of the boundary-layer on wing pressure be calculated, and what is its magnitude.

Q226 How should the Navier-Stokes difference equations be solved.

Q227 Which iterative method for solving linear elliptic difference equations is most rapidly convergent.

Q230 Technical report on measurement of ablation during flight.

Q250 What determines the onset of shock-induced boundary-layer separation.

Q261 Solution of the Blasius problem with three-point boundary conditions.

Q264 References on Lyapunov's method on the stability of linear differential equations with periodic coefficients.

Q266 Work on flow in channels at low Reynolds numbers.

QUESTIONS

Q268 What mode of stalling can be expected for each stage of an axial compressor.

Q269 Has a criterion been established for determining the axial compressor choking line.

Q272 Has a theory of quasi-conical flows been developed, in supersonic linearised theory, for which the upwash distribution on the lifting surface, apart from being a homogeneous function in the co-ordinate, is permitted to have a quite general functional form.

Q273 How does scale height vary with altitude in an atmosphere.

Q274 Jet interference with supersonic flows - theoretical papers.

Q317 Has anyone investigated theoretically whether surface flexibility can stabilize a laminar boundary layer.

Q323 How do large changes in new mass ratio quantitatively affect wing-flutter boundaries.

Q360 In practice, how close to reality are the assumptions that the flow in a hypersonic shock tube using nitrogen is non-viscous and in thermodynamic equilibrium.

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APPENDIX II

SETS OF DOCUMENTS SUBMITTED FOR RELEVANCE DECISIONS

Question	Documents
79	1302, 1317, 1436, 1437, 1572, 1575, 1672, 1967, 2111, 2313, 2319, 2379, 2391.
100	1321, 1324, 1335, 1378, 1383, 1569, 1572, 1608, 1655, 1671, 1785, 1786, 1787, 1788, 2076, 2155, 2364, 2367.
116	1317, 1435, 1569, 1574, 1575, 1576, 1578, 1605, 1608, 1656, 1666, 1972, 1993, 2002, 2153, 2155, 2391.
118	1324, 1378, 1436, 1437, 1509, 1575, 1576, 1666, 1667, 1670, 1695, 1707, 1779, 1880, 1964, 1978, 2099, 2100, 2274, 2319, 2391.
119	1302, 1324, 1378, 1383, 1406, 1437, 1476, 1569, 1572, 1576, 1606, 1618, 1666, 1667, 1670, 1798, 1916, 2076, 2082, 2084, 2274, 2318, 2391.
121	1311, 1406, 1416, 1588, 1589, 1590, 1681, 1772, 1788, 1836, 1994, 1988, 2076, 2111, 2321, 2322.
122	1360, 1572, 1597, 1598, 1605, 1688, 1708, 1713, 1748, 1783, 1792, 1972, 1995, 1997, 2319, 2339, 2342, 2391, 1619, 1508.
123	1594, 1596, 1597, 1598, 1608, 1622, 1672, 1696, 1708, 1709, 1711, 1782, 1965, 1972, 1996, 1997, 2100, 2104, 2317.
126	1311, 1415, 1416, 1443, 1597, 1671, 1672, 1676, 1687, 1710, 1794, 1799, 1972, 1995, 2076, 2150, 2153, 2154, 2338, 2341.
130	1316, 1317, 1467, 1569, 1572, 1605, 1667, 1676, 1680, 1681, 1682, 1683, 1700, 1703, 1706, 1920, 1921, 1967, 1985, 2075, 2111.
132	1335, 1378, 1406, 1443, 1569, 1572, 1606, 1608, 1620, 1697, 1710, 1783, 1799, 1874, 1880, 1972, 1973, 2144.
136	1311, 1317, 1436, 1613, 1614, 1615, 1616, 1617, 1618, 1619, 1620, 1621, 1622, 1966, 1991, 1997, 2153.
137	1311, 1316, 1415, 1420, 1572, 1621, 1675, 1682, 1683, 1699, 1709, 1711, 1793, 1794, 1795, 1796, 1797, 1799, 1916, 2338, 2341.

Question	Documents
141	1360, 1666, 1691, 1698, 1785, 1967, 1982, 1983, 2077, 2100, 2150, 2274, 2340.
145	1316, 1415, 1671, 1675, 1676, 1677, 1682, 1683, 1692, 1693, 1694, 1698, 1699, 1700, 1701, 1702, 1703, 1704 1705, 1706, 1748, 1779, 1792, 1794, 1796, 1919, 1921, 2339, 2342
146	1576, 1681, 1688, 1699, 1700, 1701, 1702, 1703, 1705, 1706, 1779, 1792, 1921, 2001, 2077, 2154, 2157, 2274, 2319, 2339.
147	1311, 1316, 1320, 1415, 1574, 1622, 1681, 1683, 1700, 1701, 1708, 1709, 1711, 1712, 1713, 1792, 1797, 2339.
148	1436, 1509, 1618, 1688, 1699, 1717, 1719, 1786, 1968, 1982, 2001, 2002, 2379.
167	1321, 1415, 1416, 1575, 1589, 1676, 1681, 1688, 1699, 1700, 1792, 1798, 1800, 1916, 1919, 1920, 1921, 2155, 2342.
170	1320, 1420, 1572, 1605, 1655, 1675, 1688, 1693, 1694, 1695, 1700, 1717, 1787, 1794, 1971, 2075.
181	1302, 1576, 1671, 1688, 1691, 1710, 1798, 1966, 1967, 1970, 1972, 2061, 2083, 2157, 2364, 2391
182	1322, 1383, 1420, 1569, 1572, 1578, 1605, 1656, 1667, 1676, 1681, 1683, 1701, 1920, 1964, 1965, 1967, 1968.
189	1416, 1575, 1588, 1590, 1592, 1710, 1788, 1968, 1971, 1985, 1986, 1988, 1989, 1990, 2157.
190	1591, 1680, 1681, 1682, 1688, 1700, 1704, 1705, 1916, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 2074, 2078, 2082, 2187.
223	1324, 1360, 1572, 1578, 1666, 1692, 1693, 1694, 1695, 1696, 1697, 1702, 1971, 2074, 2075
224	1383, 1405, 1572, 1675, 1677, 1687, 1692, 1693, 1694, 1695, 1792, 1794, 1971, 1972, 2074, 2075, 2076, 2077, 2274, 2342
225	1311, 1335, 1360, 1383, 1406, 1436, 1569, 1572, 1588, 1655, 1671, 1687, 1688, 1796, 1971, 2075, 2076, 2077, 2155, 2187.
226	1451, 1666, 1667, 1680, 1681, 1703, 1916, 2078, 2080, 2081, 2082, 2083, 2084, 2085, 2087, 2088, 2100, 2111

Question	Document
227	1451, 1575, 1672, 1677, 1680, 1681, 1719, 1785, 1793, 1916, 2076, 2081, 2082, 2085, 2087, 2088, 2111.
230	1311, 1351, 1589, 1670, 1704, 1707, 1792, 1968, 1983, 2099, 2100, 2101, 2103, 2104, 2157, 2274, 2313, 2319.
250	1311, 1316, 1335, 1415, 1415, 1569, 1575, 1675, 1793, 1794, 1797, 1798, 1799, 1966, 1974, 2077, 2154, 2157, 2187, 2274, 2313, 2319, 2364, 2367.
261	1320, 1321, 1322, 1476, 1672, 1787, 1794, 1974, 1978, 1981, 2081, 2082, 2083, 2087, 2088, 2099, 2274, 2319.
264	1360, 1367, 1451, 1590, 1671, 1672, 1677, 1680, 1681, 1719, 1916, 2081, 2082, 2087, 2088, 2111, 2316.
266	1351, 1575, 1667, 1670, 1705, 1710, 1712, 1795, 1916, 1919, 1964, 1965, 1967, 1972, 2078, 2080, 2082, 2084, 2364.
268	1588, 1589, 1590, 1592, 1619, 1680, 1772, 1786, 1787, 1788, 1967, 1978, 1985, 1986, 1987, 1988, 1990, 2078, 2318, 2322.
269	1311, 1367, 1476, 1588, 1589, 1590, 1591, 1592, 1596, 1672, 1710, 1772, 1787, 1987, 1988, 2088, 2100, 2187, 2317.
272	1415, 1676, 1677, 1680, 1681, 1682, 1683, 1692, 1693, 1694, 1700, 1706, 1794, 1796, 1920, 1921, 2080, 2111, 2339, 2367.
273	1302, 1378, 1578, 1606, 1613, 1614, 1615, 1616, 1617, 1619, 1620, 1621, 1622, 1719, 1799, 1983, 2102, 2103, 2150, 2274, 2318, 2379, 2391.
274	1409, 1592, 1597, 1672, 1675, 1693, 1695, 1696, 1697, 1707, 1970, 1971, 1973, 1974, 1993, 1995, 1997, 2061, 2075.
317	1383, 1406, 1572, 1606, 1793, 1797, 1798, 1981, 2076, 2099, 2100, 2313, 2319, 2321, 2322, 2367,
323	1594, 1606, 1671, 1675, 1676, 1696, 1699, 1704, 1705, 1779, 1793, 1794, 1799, 1879, 1965, 1972, 1973, 2111, 2338, 2339, 2340, 2341.
360	1317, 1406, 1437, 1569, 1572, 1574, 1575, 1576, 1578, 1656, 1666, 1667, 1691, 1708, 1798, 1983, 2157, 2274, 2313, 2316, 2317, 2318, 2319, 2391.

APPENDIX III

RELEVANCE JUDGEMENTS

IIIa Original judgements for Cranfield II

IIIb Judgements by Scott

IIIc Judgements by Boolean

IIId Judgements by MacAdam

IIa

Question	Documents
79	1302, 1436, 1437
100	1785, 1786, 1787, 1788
116	1317, 1574, 1575, 1576, 1578, 1656
118	1324, 1378, 1666, 1667, 1670
119	1324, 1329, 1378, 1666, 1667, 1670, 2391
121	1588, 1589, 1590
122	1597, 1598, 1688, 1708, 1713
123	1594, 1596, 1597, 1598
126	1672, 1799
130	1680, 1681, 1682, 1683
132	1406, 1606, 1608, 1710
136	1613, 1614, 1615, 1616, 1617, 1618
137	1420, 1793, 1794, 1795, 1796, 1797
141	1691
145	1698, 1699, 1700, 1701, 1702, 1703, 1704, 1705, 1706, 1779, 1792, 2289, 2339
146	1681, 1698, 1699, 1700, 1701, 1702, 1703, 1779, 2289, 2339.
147	1708, 1709, 1711, 1712, 1713
148	1717, 1719, 2001, 2379
167	1916, 1919, 1920, 1920, 1921
170	1360, 1605
181	1966, 1967
182	1964, 1965, 1967, 1968
189	1985, 1990
190	1984, 1985, 1986, 1987, 1988, 1989, 1990
223	2074, 2075
224	1687, 2074, 2075, 2076, 2077
225	1569, 1572, 1655, 1687, 2076, 2077
226	2078, 2080, 2081, 2082, 2083, 2084, 2085
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