Measuring Groupware Effectiveness using Ordinal Questionnaire Data with AI/Fuzzy Mathematics and Correspondence Analysis Treatments

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Abstract

The results of a longitudinal study of groupware technology carried out over a 2 year period within a single organization is presented. The results of ordinal data derived from a questionnaire employed to determine user judgements of the usefulness of the technology for business task are analysed using a novel "best hypothesis" approach. This treatment uses formulations based upon AI and Fuzzy Mathematics and Correspondence Analysis.

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Introduction

A feature of organizational life in the last few years has been the widespread acceptance of technologies for group communication and co-ordination based upon Email and shared workspace technologies (Rudy, 1996; Finnegan & O'Mahoney, 1996; Bannon, 1998). Also, recently, support of group mediated process within organizations has tended towards consideration internet technologies, which offer an alternative technological platform rather than an essentially new set of capabilities (Bentley *et al*, 1997). Concern has been expressed about how co-operative work support tools can be understood to affect organizations (Ciborra & Patiotta, 1996; Turner, 1998), or, indeed, if they do benefit them at all (Breu & Ward, 1999). Because of the large amounts of resource committed by both public and private sector organizations to these technologies it is important to be able to measure effect at the organizational level and to develop coherent and cohesive longitudinal data. Such data have not been generally available because, often, a case based and overwhelmingly qualitative analysis has been preferred (Orlikowski, 1992; 1996; Bikson, 1996; Hassall & Macefield, 1995). This paper presents the results of a longitudinal study of groupware effect within a single organization where measures are developed based upon ordinal data derived from a series of focused questionnaires. An analysis of the results is offered based upon some principles from artificial intelligence (AI) and fuzzy mathematics; also a treatment based upon correspondence analysis.

Measuring the Effect of Groupware upon the Organization

The first question is what is to be measured? This is an especially difficult issue when considering groupware technologies since the effects of such technologies are frequently talked about in aspirational language referring, for example, to the transformational effects of such technologies (Ciborra & Patriotta, 1996; Blackler, 1994) and the inculcation of flexible working. Because of the difficulties of understanding exactly what it is that people working co-operatively in teams may accomplish that individuals may not, there has been a strong tendency for qualitative studies to be conducted in a range of situations Many useful insights have been generated but, overall, intra, inter organizational and longitudinal comparisons have not been possible. In part this is due to the difficulty of defining what it is that groupware and related technologies are doing for the organization; what may be referred to as *"articulating co-operative work"* (Bannon & Schmidt, 1992; Bannon, 1998).

A further problem area is that of organizational culture and of political action. Walsham (1993) for example considers that interpretative approaches are vital to understanding and evaluating the effects of any information systems or technologies on organizations. The relationship between the technological capabilities of groupware and their effect in adjusting the behaviours and structures within an organization are far from straightforward; so that Walsham considers a variety of perspectives need to be taken. For example, organizational metaphors may be chosen which match particular situations or cases; Alternatively an overarching model such as structuration may be applied. In general therefore researchers wishing to be "sociologically aware" must of necessity move away from purely quantitative methods of analysis (Smith, 1990).

A possible alternative approach is to (initially at least) ignore the effect of organizational culture and simply seek a way of measuring groupware effect or effectiveness. So, a way of proceeding is to ask the question, what are people in the organization likely to use the technology for? In the current research this question was asked of a group of managers at Northamptonshire County Council (an English Local Government Unit) whilst in discussion about measuring effectiveness of the groupware product GroupWise (Rogers & McTague, 1996). Based upon responses to this question, an agreed set of co-operative business task names was derived. It was proposed to measure the use made of

GroupWise by managers and staff in performing these business linked tasks by employing a survey instrument.

The objective of the survey questionnaires was to ask respondents to judge, for the specified business tasks; how useful they found GroupWise. These judgements were to be made on the following ordinal scale.

1. *Never employed*
2. *Seldom employed*
3. *Sometimes employed*
4. *Frequently employed*
5. *Almost always employed*
6. *Indispensable to task*

The possibility of inaccurate reporting through over or under-optimism was minimised by encouraging an honest appraisal of usefulness through focussing the questions on the technology rather than the individual. In other words, rather than asking a question that implied a measure of how the individual was performing we aimed to ask one which clearly indicates that the technology is the focus of interest

In addition to a pilot study to verify the usability of the survey instrument, a total of three surveys were conducted over a 2 year period from late 1996 to late 1998, during which the use of GroupWise was being extended throughout the County Council. Sufficient detail was gathered to make a number of interdepartmental and longitudinal analyses possible. The results presented below concentrate upon 4 units of analysis which incorporate 2 sets of multi-department data and 2 sets of single department data.

Analysis of Results - Method

The results of the surveys which have been briefly described above are expressed upon an ordinal scale. Because such a scale does not relate to an underlying valid numerical score, (it is definitional), there are few valid statistical methods of drawing inferences from the results. Ordinal or interval scales of various sorts are quite frequently employed to derive judgements from a sample population so that for example respondents may be asked to judge whether they agree with a particular statement such as..

"the information systems is …"

1. *Essential*
2. *Very useful*
3. *Of some use*
4. *Of little use*
5. *Of no use*

The treatment of the results of such a survey must be dependent upon the meaning which is ascribed to the scale and the degree of statistical rigor which it is desired to apply. Pervan and Klass in *The Use and Misuse of Statistical Methods in Information Systems Research* (1992), address this important issue by means of a discussion of various applications of these types of scales. Pervan and Klass discuss three sorts of scale, Nominal, Ordinal and Interval. Ordinal scales may be compared to true interval scales which imply a definite interval between the various points on the scale. In this case, applying to the example above, we would have to be able to assert that the "distance" between *Very useful* and *Of some use* was in some precise way equal to that between *Of some use* and *Of little use*, for example. There is a frequent confusion of ordinal scales with true interval scales depending upon the use to which the scale is being put. In particular in certain uses of ordinal scales for example; *"the rating of a characteristic" . This use is the most controversial because it interprets ordinal measures with interval characteristics as well. Here the researcher assigns numbers to reflect relative ratings of a series of statements, then uses these numbers to interpret relative differences."* (Pervan & Klass, 1992 p. 212).

This is a very easy error to fall in to when numbers are derived from survey data. In fact the ability to apply meaningful statistical tests to survey results is dependent upon the nature of the scales used to derive the results. Strictly, as Pervan and Klass (1992) illustrate, the valid use of (simple) statistical tests on an ordinal scale is limited to a Kolmogorov-Smirnov test that the distribution of results matches some expected value.

So, in the case of the judgements of usage as recorded within the surveys, we are (strictly) limited in terms of the statistical analysis of results if we proceed with what is essentially an ordinal scale.

In part to avoid this difficulty, various ways in which a frequency table derived from the responses upon such a scale can be transformed into an internally consistent set if interval data have been proposed using correspondence analysis (Bendixen & Sandler, 1995; Carroll, Green & Schaffer, 1986). However, in this case it is not proposed to follow this route. Instead two formulations are developed based upon the idea of determining the single "best" hypothesis expressed as a statement from the original ordinal scale.

Best Hypothesis using AI and Fuzzy Mathematics (Formulation 1)

Krause and Clark (1993, pp. 127-130) offer a discussion of the interpretation of imprecise or vague data based upon a set theoretic argument whereby evidence is weighted in terms of its contribution to the possibility of a particular hypothesis being true. A way to think about this approach is to consider that responses to each of the possible judgements in the ordinal scale;

1. *Never employed*
2. *Seldom employed*
3. *Sometimes employed*
4. *Frequently employed*
5. *Almost always employed*
6. *Indispensable to task*

represents a form of imprecise sensor and that the number of responses for each yields a weight distribution across these sensors.

To expand slightly, a score of 3 is a vote from the 3 sensor in favour of the hypothesis sometimes employed but, because this sensor is assumed to be offering only an imprecise (fuzzy) datum, it might also be expected to offer support for (at least) the adjoining hypotheses as well. In the Krause and Clark formulation the weightings therefore offer a range of supports for each of a number of hypotheses and the most likely hypothesis is the one which has the best support.

In interpreting the frequency table of responses from the surveys, it is proposed that the best supported hypothesis can be selected by taking the weighted sums of support for each hypothesis represented by each point on the ordinal scale and adding them. This is conceptually similar to determining the modal value for the distribution but with the assumption that a vote for, e.g., *sometimes employed*, because of the imprecise nature of the data, also carries an equal level of support for the next lowest (*seldom employed*) and next highest (*frequently employed*) in the scale. So the total support for each hypothesis is the total weighted support where the scores for each hypothesis will also be assumed to contribute 100% of their weighted score to each adjacent hypothesis. Thus, from our frequency tables of responses we can expect to get a single statement of the hypothesis that is best supported for the particular question being posed.

Conceptually, it is not difficult to come up with an empirical argument supporting this strategy, which represents a form of approximation to where the centre of gravity of the frequency distribution is. Suppose, for example, 10 persons scored point 2 on such a scale but 6 persons each scored 4, 5 and 6 respectively. The modal value might suggest that 2 (seldom employed) was the most typical response, the mean value is 3.93 (close to frequently employed). but, the interpretation proposed will yield 5 (almost always employed) as the best hypothesis. This places the best hypothesis amongst the part of the distribution with the highest concentration (weight) of votes.

Best Hypothesis using Correspondence Analysis (Formulation 2)

In correspondence analysis the results of a frequency table are analysed to show how the weight of responses are distributed in n-dimensional space (Greenacre, 1984). The dimensionality of the analysis is determined by consideration of the number of points over which the responses are distributed. For example, in the scale within the questionnaires reported here there are 6 points so that each business task has a frequency distribution of responses across 6 possible values, 1, 2, 3, 4, 5 and 6. The resulting correspondence analysis produces a distribution of weights in 5 dimensions. Moreover, because of the way the process is carried out, weightings are produced for both the business tasks and each of the scores. In effect, the weighted value for each of the tasks produces a point defined within a euclidean space of 5 dimensions which corresponds to each row of the frequency table. The equivalent weighted values for the columns produces a point for each of the possible scores.

A typical correspondence analysis shows the total weight for each row and column which is included in each successive factorial dimension in descending order of total weight. Often the greater part of the weight of both rows and columns is concentrated within the first 2 dimensions and these may be presented in graphical form with the projected position of the points for the rows and columns shown. An example is shown below in Figure 1, which also illustrates the characteristic “horseshoe” distribution of the scores (columns) within the projected space.

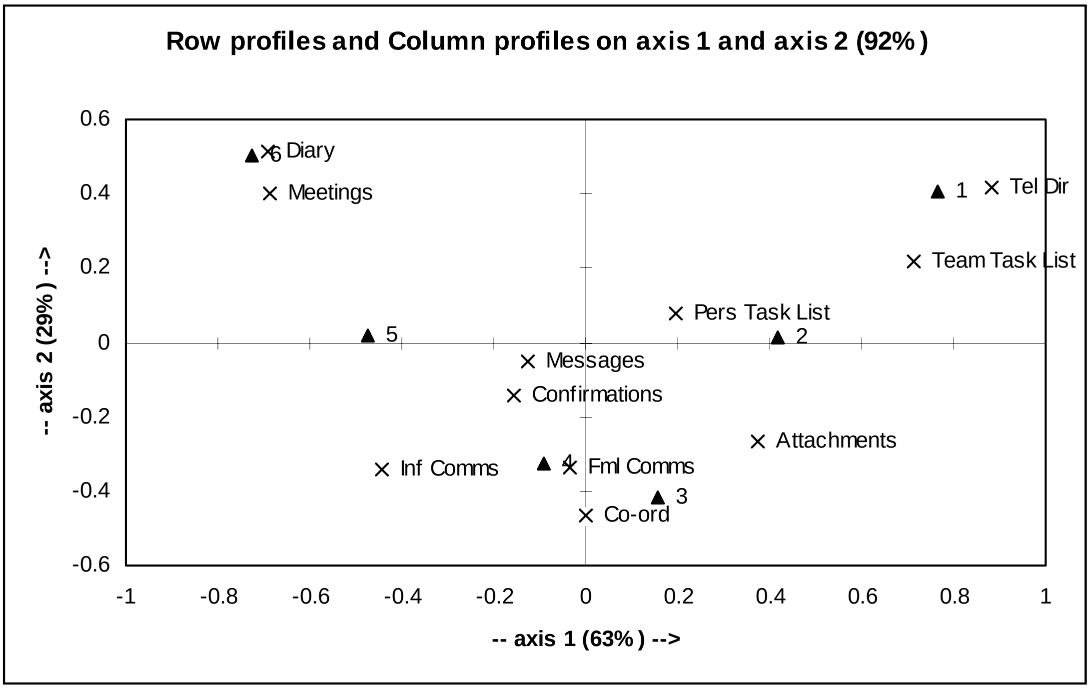

Figure 1. Correspondence Analysis, First 2 Factorial Dimensions - All Departments Survey 1

Table 1. Best Hypothesis from Euclidean Distances (Formulation 2) - All Departments Survey 1

	Euclidean Distances to Scores						
Task	1	2	3	4	5	6	**Best Hypothesis**
Inf Comms	1.431281	1.072695	0.684713	0.408932	0.464998	0.966176	4
Co-ord	1.186084	0.744338	0.225737	0.238131	0.785886	1.209317	3
Fml Comms	1.114988	0.625030	0.309367	0.292783	0.570464	1.135209	4
Attachments	0.804555	0.430263	0.274499	0.497737	0.956403	1.343555	3
Confirmations	1.126830	0.597508	0.501148	0.399784	0.445215	0.919084	4
Messages	1.009864	0.614792	0.497887	0.341310	0.370070	0.862001	4
Pers Task List	0.697779	0.312307	0.540260	0.570614	0.682887	1.057076	2
Team Task List	0.266086	0.418640	0.861727	0.989300	1.215603	1.484240	1
Diary	1.468209	1.251323	1.268420	1.047584	0.564301	0.220403	6
Meetings	1.473126	1.216645	1.184743	0.955838	0.567833	0.110222	6
Tel Dir	0.132452	0.750152	1.121825	1.229315	1.442159	1.626627	1

Because the analysis provides weightings for both rows (business tasks) and columns (scores), a possible way of interpreting the business task scores is to find out where the point representing its weightings in the 5 dimensions lies in relation to the points representing the scoring points in the scale. In other words, how close does the task point lie to each of the scale points? And it is proposed that the closest score point to each task point can be said to represent the "best hypothesis" based upon the original ordinal scale points. The distances can be calculated directly from the results of the correspondence analysis by taking the square root of the sum of the squared distances in each dimension. If this is done for the Survey 1 the results presented in Table 1 over the page are derived.

KEY
H1 : Best hypothesis using formulation 1 - AI/Fuzzy
H2 : Best hypothesis using formulation 2 - Correspondence Analysis
Mode : Modal value from frequency tables
Mean : Mean value from frequency tables

Hypotheses are
1. *Never employed*
2. *Seldom employed*
3. *Sometimes employed*
4. *Frequently employed*
5. *Almost always employed*
6. *Indispensable to task*

Business Task Details	All Departments Survey 1 (114 Respondents)				All Departments Survey 2 (120 Respondents)				Social Services Survey 2 (45 Respondents)				Social Services Survey 3 (88 Respondents)			
	H 1	**H 2**	**Mode**	**Mean**	**H 1**	**H 2**	**Mode**	**Mean**	**H 1**	**H 2**	**Mode**	**Mean**	**H 1**	**H 2**	**Mode**	**Mean**
Informal communications	4	4	4	4.277	4	4	4	3.754	3	4	4	3.556	4	4	4	3.864
Co-ordination within teams	4	3	4	3.559	3	4	4	3.415	4	4	4	3.356	4	4	4	3.580
Formal communications	4	4	5	3.580	4	3	3	3.410	4	3	3	3.422	4	4	3	3.511
Processing documents using mail attachments	3	3	3	2.932	3	3	3	3.265	3	3	3	3.133	3	3	3	3.148
Confirming delivery of communications	4	4	5	3.769	3	2	3	3.246	3	2	2	3.068	2	2	3	3.045
Recording messages	4	4	5	3.729	3	2	2	2.939	3	2	2	2.767	3	2	3	2.909
Managing a personal task list	1	2	1	3.197	1	1	1	2.991	1	1	1	2.727	1	1	1	2.864
Managing a team task list	1	1	1	2.360	1	1	1	2.379	1	1	1	1.977	1	1	1	2.466
Maintaining a personal diary	6	6	5	4.650	6	6	6	4.452	6	6	6	4.442	6	6	6	4.239
Scheduling meetings	6	6	6	4.658	6	5	5	4.078	6	5	5	4.047	6	6	5	4.011
As a telephone directory	1	1	1	2.094	1	1	1	2.426	1	1	1	2.372	1	1	1	3.216

Table 2. Results of all surveys including best hypothesis scores derived from both Formulation 1 and Formulation 2.

Discussion of Results

The results for all surveys incorporating best hypotheses derived from both formulations are shown in Table 2. In this table the modal values for the surveys, together with a mean value are also shown. The mean is included as a way of indicating something of the spread of responses when viewed in the light of the mode and best hypothesis scores.

Discussion of the results covers two main aspects. Firstly we consider what the longitudinal data may be indicating about the use of GroupWise within this organization. Secondly, and in the light of the first discussion, some consideration is given to the usefulness of best hypothesis scores resulting from ordinal survey data.

A consistency of the pattern of GroupWise use across surveys is clearly visible. Considering that this longitudinal study was carried out over a 2 year period, an issue of concern for the management of the County Council was the lack of progressive improvement in use. Indeed, a conclusion from the study was that patterns of use are established early and do not change significantly over time. This means that the initial process of implementation is very important, confirming suggestions made by Breu and Ward (1999) in relation to communications and co-ordinating software.

It is possible that some small improvement in judgements of use can be discerned between the 2 studies in Social Services but this does not appear very significant.

Another point to note are that the use for confirming delivery of communications has diminished over time. It was felt this might result from the movement away from surveying largely headquarters functions towards more operational ones. Also, that overall use across a range of business tasks could be said to lie between *sometimes employed* and *frequently employed* suggesting that few staff considered the system as a "job transforming" technology. Finally, it is clear that specific designed functions of the technology such as arranging meetings and managing a diary are preferred in use to tasks where the user has to determine how to employ the technology for a tasks him or herself (such as managing team and personal task lists).

The development of best hypothesis scores was well received by managers within the county council. It was clear that giving a definitive statement about judgements of use for a defined task might be easier to comprehend for practising managers than typical statistical presentations. Moreover, because of the way the weight of scores is taken into account in both formulations, the best hypothesis can be better than the mode in determining a particular form of "likeliest" response where the inherently fuzzy nature of an ordinal scale is concerned. The best hypothesis approach offers a way of evaluating ordinal data which is sensibly based in empirical considerations of where the weight of responses lie.

Conclusions

A method for measuring groupware use through an ordinal scale based questionnaire instrument applied to judgements of usefulness for business tasks has been developed and data analysis derived from 2 year longitudinal study within a single organization demonstrated. Best hypothesis scores derived through the AI/Fuzzy Mathematical approach and Correspondence analysis present a potentially useful method for measuring groupware and other information systems effects. Within the study described the rapidity with which patterns of use of technology are established and their persistence over time is a notable finding.

There are plans to extend the use of the best hypothesis approach across a range of survey research situations. Further, it is intended to develop surveys of groupware (and intranet) use across other organisations and technologies.

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