

Accounting for Communication: Estimating Effort, Transparency and Coherence

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Abstract

The position advanced in this paper is that the effective application of psycholinguistic models and techniques to the design of collaborative systems requires a more detailed analysis of the processes of repair. Although the analysis of communication is critical to understanding and supporting cooperative activity, the successful application of psycholinguistic approaches is restricted by some methodological and theoretical problems. It is proposed that progress can be made on these problems by developing a systematic, reliable analysis of repair. In support of this, metrics of collaborative effort, communicative transparency, and communicative coherence are proposed.

Introduction

Detailed empirical studies of the organisation of collaborative work repeatedly highlight the central role of communication in sustaining cooperative activities. This concern with communication emerges in a number of distinct ways. For some authors the relationship is constitutive; collaborative work is negotiated order. Strauss (1988) documents how task allocation in cooperative work is achieved through the operation of a 'working division of labour'. The processes involved in organising and aligning cooperative activity in this way are referred to as articulation work. This is not simply because a working division of labour is maintained in some passive sense through interaction. It also reflects the way in which workplace tasks and subtasks are articulated in the sense of being constituted and defined through the process of interaction. Hughes et. al. (1992) propose a similar analysis; "the separation, individuation and combination of activities is accomplished in an accountable way through a collectively developed, negotiated and evolving knowledge and practice" (p.117). Perhaps the most radical proposal in this spirit is Jirotka et. al.'s (1992) suggestion that the notion of 'organisation' itself should be understood as essentially performative; constituted by and through the positioning of specific communicative acts of individuals. For other authors the emphasis is on the strategic role of communication in the management of collaboration. In a

series of studies Heath and colleagues have identified recurring themes in the way individuals adjust their patterns of communication, including through the deployment of workplace artifacts, to sustain collaborative activity (e.g., Heath, et. al. 1993, Heath and Luff, 1992). For example, 'outlouds' are a class of utterances that have a broadcast character which helps to manipulate the visibility of activities to members of a team without being addressed to any specific individual or requiring any specific acknowledgement.

These studies of the social and organisational context of collaborative work make it clear that a sound theoretical understanding of human communication is critical to the successful design of information systems. This applies not just to systems that are designed to provide direct support for interaction; for example as communicative media or communicative agents, but, in effect, to any system which embodies a model of collaborative work organisation. These studies highlight the fact that a model of workflow or a collaborative task analysis is also, inevitably, a model of communication. Models that ignore the dynamics of communication and its role in reconfiguring task distribution through the 'working division of labour' are unlikely to inform design in an effective way.

Despite the elegance of the empirical observations, workplace studies of the kind mentioned above have also been widely criticised for failing to provide practical tools or techniques to support information system design. The models and techniques for the analysis of communication developed in the psycholinguistic tradition are, arguably, better adapted to the task of informing design. The emphasis is on isolating general principles and models that apply across a range of instances. This paper begins with a review of some current applications of psycholinguistic theory to the problems of system design. It is suggested that there are some significant limitations with these approaches which may be addressed by placing more emphasis on the analysis of repair.

Psycholinguistic Approaches

One of the most important approaches to modeling communication is the collaborative model of dialogue (CM) developed by Clark and co-workers (e.g., Clark, 1996; Clark and Schaefer, 1989; Clark and Wilkes-Gibbs, 1986). This provides an account of the interactive process through which people build up their common ground during interaction. The CM account is developed around the observation that the parties to an interaction only consider an utterance or other communicative act to have been added to common ground where some positive evidence for its successful completion has been obtained. The CM account of the form and pattern of contributions is elaborated through the operation of this basic principle in combination with adjunct factors relating to types of evidence and degree of effort. Two of the most important elements are that; a) interlocutors always seek to reduce the joint, as opposed to individual, effort necessary to successfully ground a communicative act and b) interlocutors ensure that a contribution has been grounded only up to a criterion level (the grounding criterion) which is adjusted according to circumstances.

One application of the CM has been to the characterisation of the properties of different media. Clark and Brennan (1991) identify a set of 8 constraints on grounding that derive from the signal characteristics of different media (Copresence, Visibility, Audibility, Cotemporality, Simultaneity, Sequentiality, Reviewability and Revisability). These constraints alter the ease with which particular types of feedback can be provided and consequently affect the grounding process. The constraints are linked to the process of grounding by reference to the costs they exact on grounding techniques (Formulation costs, Production costs, Reception costs, Understanding Costs, Start-up costs, Delay costs, Asynchrony costs, Speaker Change costs, Fault costs, Repair costs). During interaction, individuals must make a trade-off between the different types of action they can undertake in order to ground a particular contribution and their relative costs in a particular medium. For example, where turn taking costs are high individuals may invest more in the construction of each utterance and less in attempts at concurrent feedback. A pattern of small, installment, contributions is therefore consistent with a situation in which, say, turn costs are low and/or the grounding criterion is high.

The CM has also been applied to the problem of improving the relevance of the feedback provided by a system. A number of levels at which an action is considered complete can be distinguished. For example, an utterance may be perceived but not understood, or it may be understood but the action it proposes cannot be undertaken. The levels are ordered according to the principle that feedback which indicates completion at a higher level presupposes completion at a lower level; if I comply with your request

then this is evidence that I have also heard and understood it. Consequently, the current state of the common ground with respect to communicative action can vary depending on the degree of grounding that has been secured. The maintenance of context in interaction with a system can be supported by giving feedback which is relevant to the level of grounding that a particular action has achieved (Brennan, 1998). The level of feedback can be further modulated by the risks associated with possible misunderstandings.

Traum and Dillenbourg (1996, 1998) develop this approach further, making the relationship between grounding costs, grounding criterion and groundedness for a given action formally explicit. They further suggest that, rather than treating the levels of grounding as degrees to which a particular communicative action has been grounded the balance of costs can be analysed separately for each level at which a given action may be grounded. This acknowledges shifts in the balance of the grounding criterion according to circumstances and provides a means of characterising different kinds of tradeoff at different levels. For example, a video link might make it relatively easy to catch someone's attention but, without audio, make it difficult to obtain their understanding of a complex message. By contrast, the specification of content in text messages is relatively easy but it may be harder to determine whether a message has been received. At each level, the trade-off between grounding strategy and choice of media may be different.

Some important communication phenomena are, however, not readily addressed by CM-based analyses. One problem relates to the observation of distinct semantic communities within a workplace (Robinson and Bannon, 1991; Schmidt and Bannon, 1992, Savage 1987). For example, in their study of air traffic control rooms Hughes et. al. (1992, 1993) noted the use of a local set of communicative conventions, including the use of artifacts such as flight strips, that amount to a domain dialect. Although in part, these local sub-languages reflect differences in expertise Healey (1997, in prep) and Garrod and Doherty (1994) have shown experimentally that different semantic conventions can develop within different groups even where expertise is controlled. Although a contribution based approach is not incompatible with these observations, the focus on the development of dyad-specific personal common ground has led to a neglect of the processes by which personal common ground becomes established as communal common ground. In general, communal common ground, which may include knowledge of dialects, is treated as a given and the factors which influence how personal common ground develops into communal common ground are not directly explored (cf. Wilkes-Gibbs and Clark, 1992). The workplace studies indicate that these issues may be important for the design of information systems in many contexts.

A more specific, but related, difficulty is that the mechanisms for securing contributions at different levels do not address the resolution of interpretive or semantic differences between individuals. Communicative problems are analysed as situations in which a proposed contribution, usually a referring expression, fails to secure adequate evidence for its acceptance at some level. Where the resolution depends on a shift in level, the CM model provides constraints on the form of the solution. However, if an individual's contribution at a particular level fails, there is only a general expectation that some repair will ensue involving perhaps paraphrasing or reformulating their contribution in a way that is acceptable to the addressee(s). To this end a number of possible types of reformulation e.g., alternative descriptions, installment descriptions and trial references, are distinguished, but the pattern of choice amongst these types and its consequences for the success of a repair are not addressed. As a result, although it is explicitly acknowledged that processes of conversational repair play a critical role in sustaining the mutual-intelligibility of interactions (e.g., Brennan, 1998, Clark 1996), no specific mechanism is provided for dealing with changes in interpretation. One upshot of this is that there is no theoretically motivated reason to expect that a repair such as a reformulation or a paraphrase should be any more or less interpretable than the problematic utterance it replaces. An account of this process is important for situations, such as those cited above, in which conflicts in the semantics of domain related language are encountered. It is also necessary to account for what Schegloff (1992) claims is the "striking observation" that repairs are often highly precise in their diagnosis of interpretive problems and in the majority of cases are highly effective.

There is also a more practical, methodological issue. A problem with applying the contribution model to the analysis of interaction is that there is currently no means of doing the accounting necessary to analyse the trade-offs. A systematic comparison of the costs and benefits imposed by different media and requires some quantification of the communicative effort invested in an interaction and establish what level of understanding interlocutors consider sufficient in a given case. Without some means of comparing the grounding criteria being employed in different cases i.e., of estimating the grounding criterion the analysis can only have heuristic value. Providing for systematic comparisons of this kind would greatly improve the value of the information for information system design.

A number of authors have attempted to provide quantitative analyses of communication and the properties of different media in supporting interaction. Some studies in this area have focussed on primarily structural measures of interaction such as; turn-taking, interruptions, backchannels and gaze to the analysis of computer-mediated communication (e.g., O'Conaill, Whittaker and Wilbur, 1993, O'Malley et. al., 1996, O'Malley et. al. in

prep, Sellen 1992, Sellen, 1995). Although these measures discriminate some aspects of computer-mediated interaction from face-to-face or aurally-mediated exchanges, the coding categories are relatively coarse and do not take account of communicative function. For example, the category of 'interruptions' is formulated in terms of overlapping speech where, for example, there has been no signal that a speaker is relinquishing the floor. It is acknowledged that this conflates, for example, accidental overlap, disruptive or competitive interventions and cooperative interventions such as collaborative completions. Consequently, different distributions of e.g., numbers of turns, lengths of turn and interruptions are consistent with a number of interpretations and provide ambiguous information for system design (cf. Anderson et. al. 1997). Doherty-Sneddon et. al. (1997) Anderson et. al. (1997) address these problems by using variants of a cooperative task which has a reliable dialogue coding system developed for it (Kowtko et. al. 1991). The coding scheme used in this work characterises the functional structure of the dialogues, analysing utterances as moves (e.g., instruct, explain, check, clarify, query-w, align) and structured sequences of moves composed into games. This work has successfully isolated, for example, which aspects of face-to-face interaction are successfully supported by video-mediated communication and which are not.

Although it provides a systematic basis for comparisons between media and situations, this kind of functional analysis has some limitations. The coding system was designed to exhaustively classify utterance function in the map task. As a result the move types are tailored to the transactional character of the task and although it does appear to generalise well to some other information exchange tasks it is unclear whether the coding scheme is adequate for qualitatively different kinds of exchange such as competitive negotiation. Also, because the coding system is exhaustive every utterance in a corpus, or fragment, is analysed. This inevitably means that the sensitivity of the coding system is traded-off against its coverage (cf. Carletta et. al. 1996). Lastly, a significant concern in studies of computer-mediated communication is that the novelty of the technology or the situation may itself generate additional but, in task terms irrelevant, exchanges (cf. Anderson et. al. 1997). A functional game structure *per se* is not equipped to distinguish between, say, those exchanges which bear directly on task performance or coordination and those which may be strictly superfluous to the task.

Repair and Coordination

The claim of this paper is that a promising way to overcome the difficulties identified above is by focussing more attention on the processes involved in communicative breakdown and repair. A detailed framework for the analysis of repair has been developed in the conversation analytic tradition (e.g.; Schegloff, Jefferson and Sacks,

1977; Schegloff, 1987, 1992). The CA model provides a potentially powerful set of discriminations which could be used as a basis on which to analyse communicative coherence. There are three aspects to the CA model which are of particular relevance; the structural or procedural elements, the analysis of specificity and the analysis of repair type.

The basic structural distinctions in the CA repair framework involve distinguishing which participant initiates a repair, where in the turn taking structure it occurs, and the subsequent trajectory of the repair to completion. For example, self-initiated repair occurs where the speaker identifies a problem with their own utterance. Other-initiated repair refers to situations in which some other party to the conversation signals a problem with an utterance. The signaling of a problem and its resolution may occur in a variety of positions. For example, first position repair occurs in the turn in which a problem occurs, second position occurs in the next turn that occurs as a response to the problem turn. Third position repair-initiation occurs in the next turn that occurs as a response to the second position. In addition to their location within the basic structural framework, repair initiations can also be distinguished according to the specificity with which they localise a problem. For example, Schegloff et. al. (1977) propose a non-exhaustive ordering of other-initiation types where the most general kind of initiation is a "huh?" or "what?" followed, in order of increasing specificity, by a 'wh' question, a partial repeat plus a 'wh' question, a partial repeat and a full paraphrase or reformulation prefaced by "you mean Ö". They also note that there is a preference for using the strongest or most specific type of initiation available in any given case. This is supported by the observed tendency to interrupt weaker initiations with stronger initiations and, where several initiations occur in sequence, for an increase in strength of initiator as they progress. The third important aspect of repair the CA model provides is a characterisation of repair types. This is based on the recognition that certain kinds of trouble recur regularly in conversation. These are mostly familiar problem types such as establishing a reference, problems with assignment of floor, problems with assigning action types (e.g., serious or ironic, question or assertion) and problems with word selection, grammatical constructions and person references.

The aim here is to illustrate the potential to exploit this model of repair as a basis for developing metrics that can be used for analysing in more detail the effort invested in sustaining mutual-intelligibility in an interaction and the trade-offs between the costs and benefits of different media. Two important qualifications are in order. Firstly, this is putting the framework to a somewhat illicit use. The CA repair model is based on the detailed contextual analysis of spoken conversations and was developed in a tradition in which statistical and/or broader theoretical generalisations are specifically eschewed (e.g., Schegloff,

1992 - although see Frohlich, Drew and Monk, 1994, Hirst, 1990).

The second qualification, a corollary of the first, is that it is an open question whether the categories discriminated by the model can be reliably or reproducibly identified by independent judges. Although there is a large body of research which has applied these analyses to a wide variety of examples, the accuracy or degree of agreement between different individuals has not been tested. This is a prerequisite for the applications proposed here and must be evaluated in future work. The ultimate justification of the current proposal is whether a useful, practical adjunct to existing analyses can be developed.

A central claim of the CA approach to repair is that it does not presuppose an underlying model of what is being communicated or a theory of error. For example, Schegloff (1992) suggests that:

"adequacy of understanding and intersubjectivity is assessed not against some general criterion of meaning or efficacy (such as convergent paraphrase) and not by 'external' analysts, but by the parties themselves vis-‡-vis the exigencies of the circumstances in which they find themselves." p.1338

The focus is thus on analysing the situations which interlocutors themselves encounter as problematic independently of accounts of what is being transacted in a given exchange. For current purposes, the benefits of this strategy are twofold. It provides the basis for a task-independent analysis of communicative coherence that can be applied across a range of interactions. It also promises to improve the validity of the analysis by concentrating only on those exchanges in which problems occur. A critical assumption underlying this proposal is that, relative to other kinds of exchange, the frequency with which problems are signaled and addressed depends directly on their importance to the success of the interaction. This assumption obtains some empirical support from the observation in the CA literature that turns which initiate repair are dispreferred (e.g., Schegloff et. al. 1977).

The most obvious basic index of interaction that this approach can provide is a measure of the difficulty of an interaction. One means to measure this would be the proportion of turns in an exchange that are used for repair. However, this does not discriminate between 'extra' turns that do not bear directly on the main business of the interaction and those necessary to complete it. A more effective measure of difficulty would be provided by calculating the average number of turns in a repair sequence.

In the current context, a potentially more useful measure is an index of communicative or collaborative effort that individuals invest in sustaining the mutual intelligibility of

an interaction. This can be provided by analysing the ratio of repair initiations to completions undertaken by interlocutors. This quantifies the effort invested in resolving communicative problems that arise in the course of their task independently of the background frequency with which problems are encountered. It is also independent of the ways, or media, in which problems are encountered and other task characteristics. As a result, this could provide a basis for comparing, for example, the effort required to achieve a particular level of task performance under different communicative conditions.

The distinctions between the positions in which repairs may occur and who initiates them can be exploited to develop measures of the ability to detect problems under different conditions; in effect, an index of communicative transparency. The typical pattern of repair initiations is heavily skewed towards self-initiated, first position repairs (Schegloff, et. al. 1977). This pattern depends, amongst other things, on how easy it is for the parties to an interaction to detect possible troubles or mismatches in interpretation. For example, we would expect the distribution of repair initiations to be shifted towards first position self-initiation in situations where speakers are most readily able to detect communicative problems. Conversely, where task factors or media conditions make problems harder to detect we would expect a distribution of repair initiations that is shifted more towards other-initiated, second position and self-initiated third-position repair.

The dependence of the distribution of repair initiations on task conditions is illustrated by preliminary analysis of the distribution of repairs in the corpus collected by Healey (1996). The comparison is between dyads composed of individuals from the same semantic sub-community with dyads composed of individuals from different sub-communities. The prediction is that, in the absence of any explicit cues to sub-community membership, degree of semantic coordination is difficult to detect and will tend to become apparent late in an exchange where, once an utterance has been produced, possible problems can be identified and signaled. As a result, interactions between dyads from different sub-communities should rely relatively more on other-initiated, second position repair than dyads from the same sub-community. This pattern is followed in the corpus; in the *ësameí* dyads first position repair-initiation is approximately twice as common as second position, in accordance with the pattern established in the literature. By contrast, in dyads composed of individuals drawn from different semantic sub-communities other-initiated, second position repair is as frequent as first position self-initiated. This approach also provides a basis on which to compare different media. A distribution of repairs which is biased towards first position repair suggests a high level of transparency. By contrast, a relative shift towards second and even third position repair would suggest low transparency. The more a medium

regards the detection of problems the less effective its support for maintaining mutual-intelligibility.

Another interactional measure of potential value to system design can be derived from an analysis of the specificity of the problems encountered. The ability of interlocutors to localise a problem provides an index of their communicative coherence. One possibility provided directly by the CA framework is to exploit the ranking of initiation types proposed by Schegloff et. al. (1977) as a means of ordering the specificity of repair initiations. A problem with this is that the notions of paraphrase and *ëwhí* question are clearly more language specific than the notions of turn, position and initiation. This restricts the applicability of the analysis since it makes it difficult to track, for example, how different media may influence the distribution of functions between modalities. An alternative possibility is to analyse the proportion of the preceding material that is identified as problematic. In the case of verbal exchanges, a repair that identifies a single word as a source of difficulty is more specific than a "huh?" or "What?" which identifies a whole utterance. This has the potential to generalise to graphical exchanges where, say, some part of a drawing may be circled or underlined or the entire drawing called into question. It is less clear whether this kind of analysis could be successfully generalised to video-mediated interaction although it could perhaps be applied to gestures.

For each of these indices, the power of the analysis to discriminate the effects of different task parameters and media can be enhanced by considering the types of problem encountered. Intuitively it seems likely that different media will affect different types of problem. For example, if individuals can, say, point to an intended referent then reference assignment would be more effectively mediated by video than audio. Similarly, action types, such as irony, may be more effectively mediated by audio or video than via graphical media. As for specificity, one difficulty here is that some problem types, such as grammatical corrections, are clearly language specific. Nonetheless, problem types such as reference assignment and floor assignment may be encountered and resolved in any modality.

Discussion

The basic claim of this paper is that the CA model of repair can be exploited to provide operationalisations of several notions critical for the analysis of communication. Specifically, it can improve the applicability of current approaches by providing indices of the relative difficulty of interaction, the collaborative effort invested in sustaining mutual-intelligibility, the relative transparency of an interaction and degree of communicative coherence. These indices have the potential to provide information which is of direct value to the requirements analysis and evaluation of collaborative systems. If it can provide a basis on which

comparisons of the contributions made by different media, or configurations of media to, say, coherence or transparency this would represent a significant contribution to system design. Of course, the present paper does no more than suggest a way in which these measures might be obtained. It remains to be seen whether a reliable method of coding the relevant aspects of repair can be developed and whether, in practice, it can provide productive generalisations about factors critical to the support of effective communication.

Programmatically, this proposal supports the application of psychological models of communication to the design of collaborative systems. Most of the preceding points were addressed to the question of how to quantify the possible contribution of different systems to collaboration and communication. However, there is also a broader agenda that a more detailed consideration of repair might serve. As noted in the introduction, a central feature of collaborative work is the way in which the nature and distribution of the activities themselves are frequently realigned. Traditional approaches to task analysis appeal, explicitly and implicitly, to a unique decomposition of tasks and processes that is then inscribed in a system. For collaborative systems it may be more productive to focus instead on processes of negotiation and repair as a means of supporting the working division of labour.

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