

Interaction, Collaboration and Communication: A Human-Computer Interaction Perspective

*Peter Johnson and Hilary Johnson
Computing Group, University of Bath
Bath, BA2 7AY UK, +44 (0) 1225 323217*

Abstract

This paper considers the problem of supporting collaborative information brokering. The aim is to develop information brokering environments based upon models of collaboration and supported by user interface designs through which user-user, user-agent and user-information interactions are effortless and effective.

Keywords: Collaboration, information brokering, communication, user interface design.

Introduction

The intention of this research is to consider how collaborative information brokering might be analysed, modelled, designed and evaluated from a human-computer interaction perspective. The aim of doing this is to enable the design and development of effective and usable collaborative information brokering systems that take advantage of state-of-the-art technologies but not at the expense of poor usability. To this end this paper considers collaborative information brokering in the context of use.

The development of interactive communication technologies as [1] has shown, allow us to interact with people and information in a myriad of ways, across different time zones in different geographical locations. The devices we use range from mobile phones, wearable and palm-held devices, embedded devices to room size multi-media environments. With this technological development has come a significant change in the use of computers from being data processing and information storage devices to becoming communication and information gathering devices. The range of communication activities that need to be supported is vast, as are the types of information gathering and the purposes for doing so. This change in the nature and use of computing devices is both exciting and challenging to interface designers. The excitement is that it truly brings

computing into the everyday lives of wider ranges and more extensive populations of users. It offers the opportunity to bring people together and give everyone access to a greater wealth of information and knowledge, and to share their knowledge with others.

The challenges are epitomized by the fact that we are still designing interfaces to a "desk-top" metaphor when the "desk" and "office" are no longer the appropriate context, focus or medium for our communication and information needs. Moreover, the desk-top metaphor is impossible to maintain across the different range of computing devices. We are not saying that the metaphor is dead but that it cannot be extended to appropriately meet these new needs and uses of computing. We need to develop alternative and additional metaphors and ways of exploiting users' existing knowledge.

Further user interface design challenges arise from the need to facilitate interaction between people and "intelligent" agents. Appropriate models or design criteria for supporting effective interaction between people have a chequered history of success and failure in HCI and CSCW [2]. Interface design for interaction between people and agents is even less well understood, examples of poor designs are widely found and most annoyingly epitomized by the "wizard" style of agent. Studies by [3] and others have begun to empirically address these issues but as yet much needs to be understood.

It seems then that we have moved into a new phase of computing and technology but that user interface design knowledge has yet to advance to meet the challenges this has brought. This paper considers how we might progress user interface design knowledge to meet these challenges. We first consider the changes required to support emergent forms of collaboration. We then consider the issues of mobile and fixed contexts in which interaction occurs. Next, we consider the issues of information brokering and the interactions between people, agents and information that ensue. Finally, we suggest how these issues may be addressed in the design of a collaborative, information brokering and communication system.

EMERGENT FORMS OF COLLABORATION

The notion of collaboration has been much over-used in the past decade, with very few attempts at providing a firm understanding of what it entails. To exemplify and discuss a variety of different forms of collaboration, we will make use of a real-life scenario. This scenario provides a relatively rich description of the contexts in which collaborative activities can be found. At various points in the scenario a more objective description of the features of the collaboration are given.

Consider the following scenario; a family (two parents and one teenage daughter) are about to embark on a trip to a foreign country (lets call it Erehwon - after Samuel Butler's book and fictitious country of the same name). One interest they all share is natural history. Before they go they decide to find out about the wildlife, flora and fauna of Erehwon. The father decides to go to the local library to find

books on the topic. The mother writes to Erehwon tourist information office asking them to provide any information and the daughter instigates a search on the internet. Their intention is to gather as much information as they can from different sources and then share the information found with each other. Consider the scenario from a collaboration perspective.

- The family all share the same goal of gathering information about Erehwon.
- Each member of the family is separately engaged in independent activity of collecting information from different sources.
- Each separate activity will involve collaboration with others outside the family group who do not share the same goal.
- The collaborations with those outside the family group will bring them into contact with expertise different to their own.
- Prior to sharing their information with each other the family collectively but independently hold increased knowledge about Erehwon
- At some point in time the family share information with each other to increase each other's knowledge about Erehwon.

Within this scenario there are a number of different types of collaborations, for example the family collaboration in the joint goal is a different form of collaboration than the individual family members with an outside body. Here separate goals of collaboration are set up with the outside bodies. Also, the family members share a different "common ground" with each other than they do with the outside bodies [4]. A further point is that when each member of the family has gained relevant information, the family has that information but not until they begin to share their information do they each have it all.

A further point of interest is that in their individual activities they enter into collaborations with bodies (people, agents and organisations) who have forms of domain expertise that are different from their own. This is a cooperative information brokering activity.

Continuing the scenario: The father finds the library opening times from the newspaper, travels to the library and once there chooses to ask a librarian where he might find books upon the flora, fauna and wildlife of Erehwon. The librarian knows exactly where any relevant books should be, takes the father to the relevant section, searches the shelves and points out a collection of books and asks if they are what he is looking for. The father agrees that they would be worth looking at. The father browses through the collection and chooses four to take home. He then checks these out of the library and returns home with them.

Consider some of the collaborative features of this interaction:

- The librarian and the father have different levels of knowledge about where books are kept: the librarian is the expert in this domain relative to the father.
- The father and librarian for the duration of the interaction share the goal of finding information about Erehwon.
- The librarian satisfies herself that she has completed her role in the collaboration before leaving.

- The father searches the books alone.
- The activity of taking the books out of the library is yet a further collaboration but with a different goal of borrowing books.

Thus in the collaborative activity of finding the books, the father had first to explain his problem to the domain expert (librarian). The domain expert then took charge in finding the location, made sure that this satisfied the goal of the collaboration, and then left.

Returning to the scenario, the mother uses the holiday brochure to find the address of the tourist information office. She sends an email letter to the "office" and requests them to send her any information about the flora and fauna of Erewhon. She then checks her email each day waiting for a reply. After four days she receives a reply from the tourist office in which they list a number of books and leaflets, which she can order. At this point she checks which books the father has already brought home and also checks the on-line catalogue of the library to see if they have any of the others on the list. She discovers they have all but one of the books listed. She decides not to order any of the books from the tourist information office but to order all the leaflets. She sends a further email to the "office" requesting them to send her the selected leaflets. Five days later they arrive in the post together with an invoice.

In this part of the scenario we can identify further collaborative features:

- The collaboration has no identification of the individuals in the tourist office - it is between the mother and the organisation.
- The interaction is separated by long time gaps waiting for replies.
- There are separate but dependent activities of checking the books the father had obtained and checking the library stock.
- The ordering, dispatching and payment for the information are further activities with similar characteristics as above.

The collaboration here is less direct in terms of the immediacy and identities of the people involved in the tourist office. As a consequence, the extent of collaboration is less. Furthermore, there is an implicit collaboration between the father and the mother, and also the mother and the library as she checks the books and the stock lists. We consider that this form of collaboration is more than just communication, since there is cooperation between the mother and the tourist information office, and together they accomplish the goal of providing information about Erewhon.

Returning once more to the scenario, the daughter has instigated a web search on her home computer for flora and fauna in Erewhon. The results of the search return over 2,000 identified references. She browses the first 20 of these and discovers that the Natural History Museum of Erewhon appears a number of times as an information provider. She decides to follow the first of these links. As the Natural History Museum web pages are downloaded she discovers that there is a user agent available that she can use to gather information for her. She activates the

agent, which has a visual animation persona and uses speech input and output. The agent asks her what she is looking for, she tells the agent about their forthcoming trip and their interests in the wildlife and plant-life. The agent checks with her the dates of their trip, then asks if there are any particular things they want to be able to find or see. The daughter tells the agent that they will be there for the whole of July and that they have no particular things but would like to see as much as possible. The agent then acknowledges this and goes off to search the website. Meanwhile, the daughter decides to browse some of the other web sites outside the Natural History Museum. She also creates a folder with a view to storing any relevant information for later use. After a few minutes the agent returns, and asks if it convenient to show her what it has found. The daughter says it is, and so the agent begins to take her on a guided tour of the information it has recovered pointing out along the way those parts of the information that it feels she will be interested in and asks her if this is so. The daughter replies that the information looks to be just what she wanted and she asks the agent to copy the information and the location addresses where it was found into her newly created folder. The agent does this and asks if she wants any further information at this point. She replies that she does not need more information now but may want to come back later. The agent acknowledges this and records the request and retrieved information. The daughter checks that her newly created folder has everything in it and then closes down her computer.

There are several interesting features of this part of the scenario.

- The collaboration is between the daughter and a computational agent.
- The agent interacts with the user to identify the search requirements and to check the details, and then goes away.
- The daughter carries on with information gathering on her own while the agent is busy.
- The agent interacts with the user and the information to check that the information retrieved is appropriate.
- The agent keeps a note of the request and information provided for a future interaction with that user.

The direct and immediate collaboration is not people at this point but between a person and a computational agent. The agent is programmed to identify relevant search requirement information. It seeks to clarify and refine requirements before it searches but not extensively so. It then shows the user what it has found and guides them through that content checking along the way that this content is of interest. The collaboration between the agent the daughter extends to the agent storing the retrieved information for her own later use, and the agent updating its records of the user's interests and retrieved information, to make use of these in a subsequent interaction with her. It should also be noted that the daughter carries out some searching and folder creation activities on her own, without collaborating with the agent. These are in fact part of her task and form part of her contribution to the collaboration with her parents on the over-riding goal of the activity.

There have been a number of relevant features of collaboration exemplified in this scenario. Each of these features represents interesting dimensions for consideration in a conceptual framework of collaborative activities. These include the participants in the collaboration where we find:

Person-Person Collaboration

This includes collaborations between two or more people and can be between people of differing levels and types of expertise. As in the case of the father asking the librarian where to find books - the librarian has greater knowledge of where books are than the father does while the father has greater knowledge of the type of books he is looking for than the librarian. By collaborating with the librarian the father is extending the available knowledge resources. Furthermore, in this case the librarian may be expected to collaborate with users of the library as part of their job.

Person-Agent Collaboration

This includes collaborations between people and computational agents rather than human agents as in the case of the daughter using the natural history museum agent to find information on her behalf. The daughter "hands-over" part of her task of finding information to the agent while she carries on with other (in this case related) activities. This handing-over of part of a task to an agent may not necessarily be an extension of the available knowledge resource in that the agent may not know more about the information space than the user. Instead, the agent reduces the workload of the user by providing extra effort rather than increased knowledge. However, it may also be the case that an agent may bring increased knowledge to the activity.

Person - Organisation Collaboration

The collaboration between the mother and the tourist information office is an example of this type of collaboration. It arises frequently when individuals come into contact with an organisation. In this case the collaboration occurs by letter but it can occur through other media including the Internet. The collaboration does not have to identify both parties as individuals, and may never do so. A further dimension not illustrated in this scenario is that of ***organisation-organisation collaboration*** when two or more organisations collaborate in some activity. This common form of collaboration is often formally supported by explicitly specified agreements and terms and is very different from the above. Another form of this type of collaboration is ***Agent-Organisation Collaboration***. An example would be when a user agent identifies all the tourist information offices and sends an email request to each of them for information on behalf of the user.

Finally, we can also consider ***Agent-Agent Collaboration***, as when two agents work together to find information for the user or, as in the case of electronic commerce, where the user agent collaborates with the product agent to buy the user a requested item.

Another dimension of collaboration of interest identified in this scenario is that of the degree of shared goals or shared purpose in the collaboration. Along with this

is the structure or pattern of goal allocation/responsibility in the activity.

Main Goal Sharing

This is where the participants are aware of and are consciously working to the same goal. In the scenario this is best exemplified in the three members of the family (father, mother daughter) each taking on the overall goal of finding information about the flora and fauna of Erewhon. A further consideration here is how the participants then work towards achieving that main shared goal. There are a number of possibilities, which include:

1. Working on the complete set of activities together

Distributing component activities to sub-groups, while still being aware of the main goal and how each of these contributes to the main goal.

Combinations of the above where some activities are distributed and others are undertaken collectively by the whole group but at all times each member knows what they are contributing to the main goal.

In the scenario example the family distribute amongst themselves component activities of searching for relevant information in different information resources. The intention being that at some point they will come back together and begin to share that information with each other.

Distributed Contributing Goals

These occur when one or more members of the collaboration are given or take on goals but are unaware of what or how these contribute to the main goal. In the scenario there are many examples of this for example most obviously in the collaboration between the father and the librarian, and also between the mother and the tourist information office and the daughter and the agent. Thus these parties are not part of the collaboration in the main goal but are collaborators in component activities. Furthermore, their collaboration in these component activities is such that only parts of these have been distributed to them. As in for instance, the father asking the librarian to help him find the relevant section of the library, and yet not help him find the relevant information in the books. The librarian in this example has no knowledge of how this activity forms part of the father's goals, (and may not need to know).

Independent Contributing Goals

This involves activities that are independent to the collaborating activities and are taken on independently. For example, when the daughter creates the folder to store the retrieved information she is acting independently of the agent with which she had previously been in collaboration to instigate the search. She is also acting independently of the rest of the family in doing this. However, it is still an activity that forms part of the main activity but in carrying it out no collaboration is sought or made. This dimension is however still a dimension of collaboration as the goals are carried out independently but are still carried out in the context of and contributing to the main collaborative shared goal. In contrast, a goal which had no contribution to make to the main shared goal, even if carried out during the collaborative activities, by one of the collaborators, would not constitute a

collaborative goal of any type. For example if the father during his trip to the library stopped off to buy groceries, or while in the library went to check today's weather forecast in the daily newspaper, these would not be independent contributing goals.

We can identify a further dimension of collaboration that the above scenario exhibits that is concerned with the immediacy, both spatial and temporal, of the interactions that occur in the collaboration. Conventionally, in the area of temporal aspects this has been referred to as synchronous and asynchronous behaviour but these terms lack the fidelity of distinction we wish to now make and are exclusive to temporal parameters.

Immediate-Proximal Interaction

This occurs when the parties' communication patterns show no temporal lags or delays during the interaction, and the parties are in close/common spatial proximity to each other. A common example of this is face-to-face direct communication, as for example when the father interacts with the librarian.

Immediate-Distant Interaction

When the interaction occurs with no temporal lags or delays but the parties are in separate spatial locations. The most common example of this is interaction via the telephone. A further example is computer-supported communication such as video conferencing where the parties have face-to-face contact but are actually in different and separate physical spatial locations. There is no real example of this in the scenario. The closest we have is the interaction between the daughter and the agent, but that depends upon us viewing the agent as having face to face communication and being in a different location.

Delayed-Distant Interaction

This type of collaborative interaction occurs when the parties are spatially distant and there are temporal lags or delays in their communicative exchanges. The most common example this is letter writing and often electronic mail. In the scenario the mothers interaction with the tourist information office is of this type. A further example would be in video-conferencing with a temporal lag in the system so that communications were not received immediately.

Delayed-Proximal Interaction

This is a less usual but perhaps the most disruptive type of collaborative interaction. It occurs when the parties are spatially proximal but there is a temporal lag or delay in their interaction. An example of this is when one of the parties stops attending to the communication and starts attending to another activity or communication. For example, when one member of the party stops listening to the other and starts to read their email. Some of these can occur through interruptions and unexpected events while others can be intentional. Furthermore, in some cases they may occur as a consequence of the activity itself.

Thus we have identified three important dimensions of collaboration. These are:

1. Collaboration Parties
 - *Person-Person Collaboration*
 - *Person-Agent Collaboration*
 - *Person-Organisation Collaboration*
 - *Agent-Agent Collaboration*
 - *Agent-Organisation Collaboration*
 - *Organisation-Organisation Collaboration*
2. Collaboration Goals
 - *Main Goal Sharing*
 - *Distributed Contributing Goals*
 - *Independent Contributing Goals*
3. Collaboration Interaction
 - *Immediate-Proximal Interaction*
 - *Immediate-Distant Interaction*
 - *Delayed-Distant Interaction*
 - *Delayed-Proximal Interaction*

These are three dimensions that form part of the rich space of collaboration. They do not act alone and each contributes to the description of any collaborative activity. Furthermore, no one collaborative activity is necessarily of one type. During the course of the collaborative activity it may move through some or all of the dimensional spaces described here. However, by identifying these types of collaboration we can understand how to support each of these and, moreover how to prevent forcing only one type or set of collaborations. The design objective must be to support each and all types and allow fluid transitions between these types as the needs of the collaborative activities change.

COLLABORATIVE INFORMATION BROKERING

The intention of this research is to consider how collaborative information brokering might be analysed, modelled and designed. The previous section presented a number of thematically related scenarios that were focused on gathering information for a forthcoming trip abroad to a fictitious country. The scenario was based on existing and developing information resources available to users. The examples of searching the information spaces of a natural history museum is very close to what is already being made available across Europe and the USA. The example was chosen because of this, and because it presents a real challenge as to how we might support users in accessing, using and enjoying the information being made available. Similarly, for many reasons, some of which are financial, information brokering is a growing activity. Information brokering is itself a collaborative activity involving collaboration between parties, including the user, the information provider and the information broker. It further involves collaboration between people, agents and organisations in all their combinations. The interactions that occur as part of the collaborative information brokering can be of all the types described above. Thus information brokering can be seen in terms of

the collaborative space dimensions. However, there is more to information brokering than just the collaborative aspects.

The scenarios described above have further properties that attempt to characterize collaborative information brokering. First, the sources of information in the scenario are varied. They include a library, a travel information office and a natural history museum. Second, each of these sources have information represented in many and different forms and their own information brokers. In the case of the library the information broker is the librarian, in the travel office we have to assume that there is some person(s) in the organisation who will find and send the relevant information. In the natural history museum we have a computational agent that acts as an information broker.

Third, we have some indication of the activities that comprise information brokering. For example, the agent tries to find out the nature of the information requirements from the user, searches the museum's information resources, presents these to the user, checks to see if the retrieved information meets the user requirements, and then stores a "profile" of the request and information retrieved for that user for subsequent interactions. Also, in the case of the librarian the information brokering is present but in a constrained or restricted form. The librarian takes the user to find the relevant section of the library, checks to see if there is any relevant information there and then asks the user if this is what he is looking for and then leaves when there is a positive answer.

Thus information brokering involves a cooperation of expertise, with the broker (in whatever form - person or agent) having expertise in locating information. In addition, the broker must have interaction and collaboration expertise. They must know how to work cooperatively with a user in order to identify their requirements, to help them find that information and to help them in assessing if it meets their needs. Consequently, information brokers need to be expert in at least two ways, collaborative working and information retrieval. A further form of expertise that might also be found is in the domain to which the information pertains. The librarian did not have any expertise in the domain of natural history, (i.e. was not a subject specialist). While in contrast the agent may well have had domain knowledge about natural history. A further consideration is in the information broker's ability to find information from elsewhere and bring it together in a sensible manner for the user. While this did not occur in the scenarios the family itself had to investigate all the sources and bring the information together. An alternative scenario might have been that one agent is used to gather information from the different sources that exist. Thus the agent would need to know what sources exist, how to search those sources and how to bring information together.

Collaborative information brokering requires a number of different types of knowledge and skill. To be effective, efficient and helpful the information broker needs to know how to collaborate with users, to know how to find information and to know something about the domain in question. In addition it involves knowing about multiple sources, how to interact with those sources in order to obtain information, and to be able to bring together information into a sensible form for its intended use.

This raises the issue of how we come to understand the intended uses of the information. In the scenarios the intended use is to enable the family to pursue their interests in flora and fauna during their trip to Erewhon. All the information gathering is only of use if, when they come to explore Erewhon they know where to look and what they might find there.

Appreciating how the information is to be used is clearly a significant factor in successful information brokering. Consider the following further extension of the scenario. Having collected the various information each member of the family tells and show each other what they have found. They establish common knowledge of what information they have, where it is and what is of particular relevance. They decide that they would like to take the most relevant information on the trip with them. The daughter volunteers to put all the relevant information on her portable computer. Once she has done this they are all set to leave. The next day they travel to Erewhon, and upon arrival decide to investigate some of the nearby countryside around their hotel. They set off together and soon find a fascinating butterfly in a hedgerow, which they cannot identify. The daughter takes out her communications book and using the digital video camera captures an image of the butterfly and activates a search of the information previously collected. The communications book responds by displaying a choice of information about the butterfly. She browses this information and discovers that it is a very rare butterfly indeed. She decides she will make notes to accompany the image she has captured of the butterfly. Not wanting to frighten the butterfly she decides to write her notes rather than speak them.

The scenario now exemplifies how the use of information is often far removed in space and time, from the point at which it was collected. Furthermore, the users of the information wanted to process and transform the information to fully meet their needs. Their usage included having portable access to the information in a time-critical situation via image recognition. Moreover, their use involved them adding information to the information space in the form of stored images and written notes. This ability to manipulate, transform and add to, or annotate information, is typical of the type of uses required. Thus we see that contextualising information usage has a number of features to consider. These include:

- The time of use may be;
 - Long after the original information was requested and collected. Consequently users may not at the time of request be able to anticipate all the types of use required.
 - Critical - access being needed immediately if it is to be of use.
- The place of use may be;
 - Distant from the point of request
 - Contextually different from the point of request
- The devices upon which the information is used may be different in their input/output capabilities.
- The form of query may be different from the original query.
- The information may be added to annotated or otherwise modified.
- The task or purpose of use may be only partially known and understood

even by the users at the time of information gathering.

- The users of the information may not be those who request it (they may be a subset or a completely different set of people).
- The knowledge users have will determine the utility of the information.

Thus, we can see that information brokering has to take significant notice of the time, place and other aspects of the prevailing context, and form of use. Moreover, it is dependent upon the task and purpose of use and the user's existing knowledge. However, it is going to be the case that these are often unknown even to the information gatherer at the time of request. One solution to this problem is to give the user more information than they actually need at the time of request. However, this may well produce information overload and interfere with the effective and efficient use of the information. This occurred in the scenario where there was information processing undertaken by the family as part of their use of the information. They decided what was relevant and what was not; they brought all the relevant information together and even transformed it to store it all on their home computer. This was the first phase of their use of the information. A second phase began when they actually started to apply the information to identify things they had found once they were on their trip. This involved information retrieval, information processing and creation of new information. Thus information brokering must enable the users to accumulate, consolidate, process, share, store, retrieve and create information. Above all it must allow them to understand and use that information to increase their knowledge at the time, place and context where it is needed and for the purposes and tasks they choose.

DESIGN AND EVALUATION ISSUES.

We now consider how to support the use, design and evaluation of collaborative information brokering. The issues raised in the previous sections provide us with a conceptual analysis of collaborative information brokering. The purpose of providing the conceptual analysis is applying it to improve the design and evaluation of usable information brokering systems.

Design metaphors

Earlier we made the point that the metaphor of the "desk-top" was not appropriate for the needs of collaborative information brokering. This was because it does not easily migrate or usefully guide the design on interactive information devices that can be used in various and varying contexts, support groups of users and their myriad uses of information.

Others have recognised similar weaknesses and have turned to alternative metaphors for guidance. One such alternative has been the use of "rooms", "offices" or "complete buildings" through which the user can navigate to find the correct information area. Within such environments the user may find documents, books, diagrams, videos, agents and face-to-face conferencing facilities to aid them in discovering the information they desire. Below, is one example of such a

metaphor taken from work by [5] depicting one scene in an information-brokering environment. Here the user can interact with information and human experts through the various media and other facilities designed within the metaphor of a "office suite".

We show this purely as an example rather than as a good or bad example of an alternative metaphor to the "desk-top" to guide and constrain the design space. With the development of virtual reality technology it is possible to provide artificial offices and buildings with all the attributes of presence, awareness, and persona used to sustain the metaphor of being "in" the information brokering environment. But while this moves us away from the desk-top it does not necessarily address the requirements of information gathering and use that we have considered in the context of the earlier scenario. The need is to interact with information, brokers, other users, in different contexts, for different purposes and on devices that are not easily constructed as, or portrayed through, "office" metaphors.

One problem that makes a single metaphor such as the office or the desk-top difficult to sustain relates to the many different types of devices and settings in which information brokering will be needed. Using mobile computers that are hand-held or wearable to access information brokering services will make it very difficult to sustain an adequate rendition of an office environment. The device size, its processing and input-output capabilities will all put serious constraints on such a metaphor. Furthermore, serious and difficult questions of quality of service on mobile devices will determine what resources are given priority at any one time. If these are prioritized according to the users current needs, context, task and purposes then it may well be the case that the environment must be able to reconfigure itself to meet these needs. Quite apart from these considerations there is a special irony in using desktop or office metaphors for mobile applications.

For example, consider the situation when the daughter was trying to identify the butterfly before it flew away using her portable hand-held "information book" she wanted to transmit and image of the butterfly and match the image with an identified butterfly in the information space. Here, the emphasis was on speed of interaction, image capture, transmission, information search and retrieval. The daughter presumably did not want to enter into a lengthy dialogue of any form and needed as efficient and effective performance as one might expect from a fast action camera. Similar requirements might be expected from users such as police in pursuit contexts when they want to be able send and receive information about at suspect.

The point is that the system will need to function appropriately for its context of use, and metaphors such as desktops and offices may not fit many of these contexts of use. The purpose of applying metaphors is to facilitate understanding and communication by maximizing the use of the user's existing knowledge, for utilization in the current context. Desktop metaphors were, to some extent, successful when the prevailing model of computer use was individual office work. This is no longer the situation.

Design analysis

The different dimensions we have identified provide some guidance as to how

those contexts may be understood and consequently how design might be progressed by their use. The intention is that the design team begin to find appropriate design solutions to meet these many and varied dimensions. The dimensions themselves do not create the design solution. They provide a conceptual model of the design problem space. Furthermore, they allow the design team to understand the complexities of information brokering. In practice the designer can use the dimensions as a means of carrying out an analysis of the design requirements. The analysis itself will involve identifying relevant features of the design space involving the users, their task and the context of use. However it can be far more complex than a conventional task analysis or contextual inquiry. It must consider the information usage over time periods, across users and across contexts of a wide scope and extensive variability.

It is envisaged that the user and communication requirements will be different depending on the different bodies collaborating. Therefore, user-user and user-agent communication will have different needs than agent-agent communication. For instance, we would be less likely to consider the role of trust in agent-agent communication than in user-agent communication where it is important that the user can have confidence in the validity of the information provided by the agent. A significant research question concerns what model ought to be followed for the different communication supports provided by the collaborative working system. Often it is the case that human-human communication is not an ideal model for human-agent communication although there are aspects which will be applicable. It is important therefore for designers to consider what the communications will be and between whom.

The next research issue relates to how people work collaboratively, and sharing of goals is one possible aspect of collaborative working. Depending on whether the goals are shared, distributed and contributing and independent and contributing indicates the degree of common ground between the collaborators. Systems should be designed which not only support but actually enhance the sharing and understanding of knowledge between collaborators. This means that the degree and type of support might change depending on whether the need is to acquire, enhance or negotiate about common understanding. This will affect design decisions about how much to make transparent to the users. In addition, knowing whether the main goal is shared or whether the current communication is between people who are collaborating on distributed but contributing goals will affect the type of information that is relevant to the collaboration. In order to design an intelligent agent, a designer needs to construct an agent that knows how to collaborate, and also how to undertake parts of the user's task(s). In this sense the designer needs to know the process by which information is exchanged between people of different expertise, and between people and agents. How can the agent identify if the information retrieved is appropriate? What is the protocol for doing this? Can the user be consistently interrupted? How can the agent make sense of the information it is to provide to the user? Does this making sense rely heavily on the context. This information needs to be established by the designer of the system and there needs to be support for the designer in achieving this goal.

Design evaluation

The evaluation of collaborative information brokering systems also presents a new challenge. The conventional experimental and discount usability evaluation techniques each have problems in addressing the issues raised here. The dimensions identified above do not tell you how to evaluate such systems. They do provide a strong identification of the features that will determine if a system is usable or not. They provide a clear identification of what needs to be assessed and the parameters that influence usability. For a system to be deemed successful as a collaborative working system, we would assume that the main goal has to be achieved or that there is significant progress towards the goal. We would also expect that the information retrieved is appropriate for use and can be applied by the receiver and that the effects of the application are greater than if the information was not known, or given.

CONCLUSION

In this paper a conceptual framework for analysing dimensions of collaboration was put forward. The dimensions are concerned with who is collaborating, whether the collaboration occurs over a main goal, or a shared contributing goal, distributed or independent, and the nature of the interaction. The interaction can be immediate or delayed depending on the task and context, and can also be proximal or distant. The dimensions were then used to think about the research and practical issues that have to be faced in designing collaborative working systems.

ACKNOWLEDGMENTS

The authors work is supported by EPSRC MNA research grant, "Collaborative Working Environments", a collaboration between the University of Bath and University of Leeds.

REFERENCES

- 1. Olsen, D. (1999) Interacting in chaos. Keynote address. IUI1999, San Francisco.
- 2. Winograd, T. & Flores, F. Understanding computers and cognition: A new foundation of design. Norwood, N.J: Ablex 1986.
- 3. Andre, E., Rist, T., & Muller, J. (1998) Guiding the user through dynamically generated hypermedia presentations with a life-like presentation agent. Proceedings of International Conference on Intelligent User Interfaces, page 21-28 San Francisco.
- 4. Clark, H. (1996) Using language. Cambridge University Press.
- 5. Dew, P.M., Leigh, C.M., Drew, R.S., Morris, D.T. and Curson, J.M. (1995) Collaborative working systems to support user interaction within a virtual science park. Information Services and Use. Vol. 15, pp. 213-228.

