Stellingen
behorende bij het proefschrift

An analysis of user interface design practice
Towards support for team communication

1. Als men als uitgangspunt neemt dat ontwerpers bewust gebruik maken van verschillende mate van detail en van verschillende media voor het onderhandelen over het ontwerp en het ontwerpproces [1, 2], dan is het belang van het kunnen maken van gebaren in ontwerpbesprekingen duidelijk, omdat het maken van gebaren een compact middel is om een minder definitief ontwerpidee te kunnen presenteren.


2. Het resultaat dat met een aan-spraak-gerelateerd ‘point’ gebaar de mate van precisie aangegeven kan worden [1], geeft aan dat er extra onderscheid kan worden aangebracht in de verschillende soorten van ‘place deixis’, gemaakt door Levinson [2], n.l. de mate van precisie van deixis.

[1] Dit proefschrift

3. Een vroege versie van ‘virtual reality’ werd ongeveer 450 jaar geleden bereikbaar voor een breder publiek, toen de boekdrukstoel werd uitgevonden.

4. Communicatie tussen mensen die een verschillende achtergrond hebben is een belangrijk probleem in ontwerpteams [1]. Opleidingen voor mensen die interactieve systemen ontwerpen, zoals Industrieel Ontwerpen, zouden daarom meer projecten in hun opleiding op moeten nemen waarbij studenten ervaring op kunnen doen in het communiceren met mensen die een andere achtergrond hebben.

[1] Dit proefschrift
5. Ondersteuning voor communicatie tussen verschillende communicatie partners zal slechts een succes zijn als alle partners tot communicatie bereid zijn.

6. Het meest vermoeiende deel van het reizen met de trein van en naar je werk is niet de reis zelf, maar het plannen om op tijd voor één van de treinen op het station te zijn.

7. De uitspraak “ontwerpers kunnen geen onderzoek doen” is niet gebaseerd op wetenschappelijk onderzoek, maar slechts op anecdotische gegevens.

8. De wonderen zijn de wereld nog niet uit; duizenden mensen bezochten het huilende Madonna-beeld in Limburg en onderzoekers bestudeerden of de traan daadwerkelijk uit traanvocht bestond.

9. De auditieve informatie die in de ondergrondse van Londen wordt verstrekt, zoals waarschuwingen en informatie over routes, is het moeilijkst te interpreteren door onervaren gebruikers die deze informatie het hardste nodig hebben. De auditieve informatie is moeilijk te begrijpen omdat enerzijds de context onduidelijk is voor onervaren gebruikers - is het een waarschuwing, zoals “Mind the gap”, of is het een routeaanduiding, zoals “Via Bank” - en anderzijds omdat de weergavekwaliteit vaak zeer laag is.

Londen, 16 augustus 1995 Mathilde M. Bekker
An analysis of user interface design practice
Towards support for team communication

PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus Prof. ir. K.F. Wakker,
in het openbaar te verdedigen ten overstaan van een commissie,
door het College van Dekanen aangewezen,
op dinsdag 10 oktober 1995 te 16.00 uur

door

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ingenieur industrieel ontwerpen,
geboren te Rotterdam
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Technische Universiteit Delft
University of Michigan
Katholieke Universiteit Brabant

ISBN 90-9008683-8
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1. What has been studied and the insights gained

1.1 Introduction to the thesis

Contemporary products and software applications offer increased functionality. In turn designing 'usable' user interfaces is becoming more complicated. Furthermore, integrating new technological developments, such as multi-media and virtual reality, into the design of user interfaces, without making the interface more elaborate is an extra challenge that designers have to meet. Support\(^1\) for user interface designers to facilitate the design process is therefore becoming increasingly important. However, before we can develop good support, we have to understand who will be using it and what sort of support is needed. The research described in this thesis relates to these research questions. Our interest lies in what design practice is like, i.e. who develops user interfaces, in what kinds of design projects and how designers think the design process can be improved through better support.

First, we will give a definition of the term user-interface designer. Not everybody who develops user interfaces actually holds the position of 'user interface designer'. User-interface design is a relatively new field, and people with very diverse backgrounds, such as computer scientists, psychologists, ergonomists, industrial and graphical designers are working in the field.

There are many different ways to study the user-interface design process: one can study projects ranging from small to very large, the emphasis can be placed on understanding the complete design process, or a portion of it, and one can choose to study the individual designer or the group process of design. All these approaches can lead to useful insights to improve design support. In this thesis we focus on small to medium sized design projects in

---

\(^1\) In this thesis the term "design support" refers to all kinds of design aids, such as design methods and tools. The distinction between design methods and tools is not always clear-cut. A design method is a list of steps that are to be taken during a design project. "Design tool" refers to something that can be used for one or more steps of the design method. In some cases a tool is developed based on a certain design method. For example, the HUFIT tools (e.g., Taylor and Galer, 1989) have been developed based on a user-centred design method. The findings and conclusions of the present study are relevant to the development of both methods and tools. Therefore, we will predominantly use the general term "design support".
which special attention is given to the design of the user interface. We include the design of products where the interface contains microprocessors. We do not include the design of products without an electronic information processing component, such as an ordinary door lock, or a stapler. Furthermore, the central focus of our study is on the early phases of the design process, e.g. on formulating the problem, gathering information and coming up with design ideas. The later parts of the process, e.g. working out the interface in more detail, and implementing the user interface are not covered in this thesis. We concentrate on the early phases of the design process, because improvements here can prevent the need for great changes in later phases of the process, and thus save considerable time and money.

1.2 Overview of the results

Design Practice: Users and design context
The overall research question that we are interested in is what design support, in practice, could assist user interface designers in designing easy to learn and use user interfaces. To find answers to this question our research is approached as (a part of) a user-centred design process (see Figure 1.1).

Within the area of products and applications design the user centred design process is an iterative process of evaluating how users work in their environment, designing a product or application and building it. Each iteration can lead to the development of an improved or completely new design. In the user-centred design process the first step is to gather information to try to understand who the user of the product will be and in what context the product will be used (e.g., Gould and Lewis, 1985; Greenbaum and Kyng, 1991). Our research question is approached in a similar way by determining who actually designs interfaces in practice, and what types of design projects are undertaken (Chapters 2 and 3).

In the past the main focus of scientific study on user-interface design practice has been on large system design projects or on the role of computer programmers (e.g., Rosson et al., 1988; Curtis, 1988). Other studies have shown that it can be difficult to apply existing methods in practice, because some methods require too much time or expertise to be applied (Grudin, 1994a; Bellotti, 1990). We decided to conduct an analysis of design practice in the Netherlands in order to determine in what situations design support is being used.
What has been studied and the insights gained

User-centred design

Figure 1.1
An overview of how the results of the research described in this thesis can be used as input for a user-centred design approach of user-interface design support. NB: Chapter 4 is not included in the overview because it describes an exploratory study on how to analyse communication in design teams.

In Chapter 2 we describe how we distributed questionnaires to people involved in the development of user interfaces, in order to determine who the users of design methods are and in what design context they usually work. The designers were asked to describe their experiences in design practice, and base their answers on a recently finished project. The results show that design projects are very diverse. The results also indicate two areas that need to be studied further: how to gather information about users and applications, and the ways in which the people involved in the projects collaborate.

Designers' needs
Having established who the users and what the design contexts were, we were able to construct a research question for the second study: what tools can improve design support according to user interface designers?

In Chapter 3, we describe how we interviewed designers about their experience in practice, and about the kind of design support they felt could improve the design process. To safeguard opinions were not restricted to any one design situation, we ensured that user interface designers working
in different areas (e.g., computer companies, product development departments, and research institutes) participated in our study. We examined what problems they experienced and investigated what kind of support might help solve some of those problems.

We found that designers need support for prototyping and for communication with other people involved in design projects. In our study discussing design ideas with other people involved in the project proved to be very important throughout the whole process. Prototypes were used to explain the design to, and elicit information from many different people, including users, programmers and clients. Also, the ability to change the prototype while discussing the design was one of the issues for which better support was requested. A related activity for which designers felt better support was needed, was gathering information about users and their tasks. The main reasons that were given for problems with gathering this information were not being allowed to contact users for fear of information leaking to a competitor, not knowing what method to use to collect the information, and too infrequent contact with users.

We decided to investigate the problem of communication in more detail, because communication is an activity that is important throughout the entire design process, and can be seen as a layer over almost all other design activities. The results of the interviews showed that design solutions had to be discussed with many people involved in the design process. Such discussions were necessary, for instance, to elicit extra information, to explain the design, or to decide how to proceed. Furthermore, many reasons were mentioned for communication being difficult. In some cases people had problems understanding other team members' representations (e.g. documents, drawings, or prototypes), because they were not accustomed to the different types of representations that were used. In other cases communication problems were caused because team members used different terminology.

*Use of representations*

In Chapter 4 we describe an exploratory study on the use of representations by industrial design students. The purpose of the study was to determine how we should analyse behaviour in order to come up with recommendations for design support. In this study we explored the use of qualitative and quantitative methods of analysing behaviour in design meetings. We studied three groups of students making a redesign of a user interface. We found that their actions were used differently for different tasks. Based on these findings we decided to use an action-
oriented versus task-oriented analysis method to determine how design support can be adjusted to the task that it supports. The results also showed that in some cases subjects would at first gesture in the air to explain some design idea, and only later draw the idea on paper. These findings showed that to understand the use of actions we should also include actions in the coding scheme that were not performed on representations.

**Communication in design teams**
The aim of the study described in Chapters 5 and 6 was to generate recommendations on how to support and consequently improve communication within design teams. Of course, there are many different aspects of communication in design projects which would merit study, but due to problems of available time and accessibility of subjects, we studied communication within homogenous design teams during meetings. We were especially interested in how team members explained their design ideas to each other, and therefore we studied meetings in which design ideas were generated and discussed.

We were interested in whether support for design could be adjusted to the task that is supported. Of the all the types of actions that design teams use for communication, the use of drawing and writing have received much attention (e.g., studies on designers using drawing support by Scrivener et al. (1993), and by Hayne et al. (1992)). Conversely, methods such as gestures have received relatively little attention. In the exploratory study described in Chapter 4 we observed that students often used gestures to explain how prospective users would interact with the product. Explaining the gestures of users, and using gestures to simulate this behaviour was an important part of explaining the design. Therefore, design support should also enable designers to use or simulate the use of gestures. Furthermore, case studies have shown that it is hard to support gestures in groupware tools (e.g., Gaver et al., 1993). Gestures have a number of attributes that make them attractive for communicative purposes: they have a low cognitive load, they take little time to prepare and relay, they can be made simultaneously with speech, and they can convey complex information in a very compact form. We were interested in how such a simple, yet powerful, means of communicating is used in design meetings. Therefore, we focused on the use of gestures in design meetings in the study described in Chapters 5 and 6.

Again, we treated the design of support for gestures as a user centred design process in the expectation that understanding the present situation
would reveal insights for the support of design teams. Thus, we studied how design teams use different types of gestures in a natural and rich setting (a face-to-face meeting). We distinguished four types of gestures: kinetic (conveying actions), spatial (showing distances between people, ideas or concepts), point (referring to an object, person or concept), and other gestures (the rest).

We were interested in whether support for gestures could be adjusted to the task that is supported, and what types of gestures are used for tasks. More specifically, we wanted to determine whether gestures are used more frequently for design related activities (e.g., explaining how the design works) than for management activities (e.g., determining who does what). We also wanted to examine how the use of gestures is influenced by the tools that groups have available. Thus, we studied how gestures are used by groups that use basic tools such as paper, pencil and a whiteboard ("unsupported groups"), and how they are used by groups that have more sophisticated support available, i.e. a shared text editor ("supported groups"). To determine what types of gestures were used for each of the activities we used an actions-oriented (four types of gestures: kinetic, spatial, point and other) versus activities-oriented (design activity, procedure activity, other activity) framework.

The results of Chapter 5 show that gestures are used for all three types of activities (design, procedure and other activities). Kinetic, spatial and other gestures are often used for design activities, and point gestures are used frequently for design and procedure activities. For every second they spent talking the unsupported groups used more gestures than the supported groups. This difference was mainly caused by the fact that the unsupported groups used more point gestures for every second they spent talking during procedure activities. We also found that in general the groups used more gestures for design than for procedure activities. The results showed that the actions versus activities framework is a useful way to determine how to adjust design support to specific tasks.

Support for gestures
Besides determining for what activities gestures are used, we also investigated how gestures should be supported (see Chapter 6). The study by Tang (1989, 1991), concerning communication within design teams in a face-to-face setting showed that gestures are frequently used for various purposes, such as engaging attention and expressing ideas. Harrison and Minneman (1994) studied the use of 3-D objects by designers, and concluded that designers use gestures for a wide range of purposes: as a
surrogate for an object, to indicate or suggest an alternative form, or to refer to locations.

Even though these studies have described the use of gestures by design teams, they do not distinguish between different types of gestures. To determine whether different types of gestures should be supported in different ways we examined what characteristics are important to convey the information contained in a gesture. We also examined what the differences were between using gestures in an unsupported face-to-face, a supported face-to-face setting. Furthermore, we discussed what problems might occur in a distributed (i.e. team members working in different locations) setting. In this way, we wanted to generate a list of recommendations on how to support gestures in supported face-to-face and distributed settings.

The results of Chapter 6 show that gestures are used for a wide range of purposes. For example, kinetic gestures are often used to show the interaction between users and the product. Point gestures are often used to refer to information related to the design. Furthermore, each type of gesture conveys information in a slightly different way. For example, for kinetic and spatial gestures 3D information of the trajectory is essential to enable interpretation, whereas for point and "other" gestures 2D information is usually sufficient. The importance of the different phases of the gestures (e.g., preparation, stroke, peak and retraction phase) also varies. For kinetic and one-handed spatial gestures the stroke usually contains the information most important for interpreting the gesture, whereas for point and two-handed spatial gestures the peak commonly conveys the main message.

We also discussed some problems of supporting gestures of distributed groups: 1) preserving the relation between the gesture and the information it refers to, 2) the distortion of the gesture because of the technology used, and 3) the inability of the speaker to know how the gesture is presented, and thus, the inability to adjust the use of gestures to the way they are perceived by the participants.

1.3 General discussion

In this section we will discuss the research approach we used and how our choices of subjects may have influenced our findings. Another important discussion point that we will discuss is whether the results that are based
on the analyses of user-interface design practice as it is today, will be valid for design practice in the future. We will discuss to what extent our results on support for gestures can be generalised to other situations than the one studied. Finally, we will discuss our contributions to the understanding of how to support user-interface design teams.

1.3.1 Research approach
In this thesis various aspects of design practice have been studied. The aim of the research was to come up with recommendations for the support of interface design. We treated the research as a user centred design process (e.g., Gould and Lewis, 1985). User centred design focuses on people, their work and their environment, and how technology can best be designed to support them (Preece, 1994). User centred design is an iterative process of design and evaluation of the design. The question is at which point to begin: the design or evaluation part of the process. Before we decided for what kind of support we wanted to give recommendations, we decided to study the prospective users of the support, the context in which the support is used, and what kind of design support the users feel they need (see Figure 1.1).

It is important to question whether our approach has led to useful insights for the development of design support, and thus whether our approach has been fruitful. The aim of our research was to determine what sort of design support is needed to improve the user-interface design process, and to come up with recommendations for effective design support. Our analysis of the users of design support and contexts of user-interface design has led to useful information for developers of design support. The information we have gathered about design practice can aid support developers in adjusting their design to their target users. Furthermore, we found that it is important for developers to clearly explain for whom they intended the design support, to ensure that the prospective users of the design support are able to select the appropriate design support for their situation. Our research indicates a number of areas for which design support can be improved, and a more detailed analysis of one of these areas, communication within design teams, has led to recommendations for support of gestures in groupware applications. We conclude that our research has led to useful input for the development of design support, it has revealed insights into who the prospective users of design support, their needs, and more specifically how some design activities should be supported.
The results concerning the users of design support and the context in which the support is used are relevant both for design methods and tools. We feel that both new design methods and tools can improve the support for prototyping and involving the user in the design process. Our findings on support for gestures are mostly relevant for the design of tools, because they concern support for communicative actions, and not for the method of communication (e.g., to prescribe steps of actions).

One might also wonder whether our choice of subjects has influenced our findings. For our research we used experienced user interface designers whenever possible. For the study on the use of gestures we decided that being able to compare the behaviour of the groups in the study outweighed the disadvantage that the subjects were not experienced designers, but MBA (Master of Business Administration) students. It is evident that there are aspects which may influence how people use gestures in design meetings, for example background, common ground (i.e. mutual knowledge, beliefs and assumptions; Clark and Carlson, 1982) and whether the group is homogenous or heterogeneous. However, we assume that using students was an acceptable solution because the subjects were being educated to perform similar tasks, they had experience with working in practice, they had worked together in the same group before, and their background was varied (i.e. their previous work and education circumstances differed).

Are our findings also relevant for related design fields, such as architecture, graphic and product design? For these fields methods and tools also have to be developed with the prospective users in mind. It is hard to say whether the process and organisation of design in such related fields is similar, and thus whether the same areas as found in this thesis require support. However, our results on the support for communication in general (Chapters 2 and 3) are relevant for these fields, because communication about design ideas also plays an important role for projects in such related areas (e.g., Cuff, 1991: on architecture in practice).

1.3.2 Design practice
Within this thesis we have studied design practice as it is "today". An important question is whether our findings will still be valid in the near future. User interface design is a rapidly changing field, more specific education is being developed, and the design process of user interfaces is also constantly being adapted to new technological developments. We will now discuss a number of the issues that are relevant to expected changes in present design practice.
The design of user interfaces is a relatively new field. During its evolution the focus of interface development shifted from the display and the keyboard, the dialogues with systems and applications to the social and work environment (Grudin, 1990). Parallel to this shift of focus in interface development the disciplines involved in the development changed. In the early phases, development was essentially undertaken by computer scientists, but over the years other professionals such as product designers, ergonomists, graphic designers, cognitive psychologists, dramatic artists (e.g. Laurel, 1993) and anthropologists have also become involved in the field. Additionally, since 1990 a new discipline has been called upon to contribute knowledge to the field: the shift from concentrating solely on the user to studying the users in their social work environment has lead to increased interest in using ethnographic methods for user-centred interface design (e.g., Shapiro, 1994).

We can assume that the user interface design field will continue its search for useful methods which contribute to the complex knowledge needed to develop easy to use user interfaces: taking into account the many-faceted problems of combining user, systems, application and social context issues in the user interface design. The diversity of design practice will, therefore, continue to be one of the challenges that developers of design support will have to meet. However, as the user-interface design field grows, and more specific education is offered, this diversity may partly decrease.

The need for specific human computer interaction (HCI) courses and schools is indeed being recognised, for example, in 1991 the Utrecht School of the Arts initiated a new education program called Interaction Design (Barfield et al., 1994). Also a survey on HCI education has shown that HCI courses have experienced a rapid growth in the 1980's and 1990's (Gasen, et al., 1994). Furthermore, special studies have been conducted to determine how education can be tailored to the demands of design practice (e.g., Strong, 1994; Hewett et al., 1992). Some of the communication problems that we found could be solved if specific HCI courses were better tuned to design practice. However, since it takes 4 to 5 years to complete such a course, and at least another 5 years for sufficient graduates to transpire into design practice, it would take at least a decade for the people who followed the "new" curriculum to get integrated in large enough numbers for the difference to become noticeable. Also, if the trend that knowledge from other sciences is assimilated into the field continues, then accordingly more refinements will be needed in the appropriate
curricula. Consequently, the misunderstandings between people working as part of a design team shall be apparent for some time to come.

The contexts of use of design support (e.g., type of company and type of design project) are very heterogeneous. Such aspects may affect the use of design support, for example, as project length varies, the time available to design varies accordingly, and as team size increases, coordination of tasks will become more complex. We have no reason to think that the contexts of use will be less varied in the future. Therefore, adjusting design support to the contexts in which they have to be used will remain as complicated as described in this thesis.

One might also wonder whether the types of products and applications being developed will change, and whether this will influence our findings? Designing applications and products is becoming increasingly complex. New developments, such as multi-media and virtual reality, give designers even more design options, and thus can make it even harder to design a user-friendly interface. Another trend that poses new challenges for the design of user interfaces is the shift from single user applications to groupware. Most of the existing design methods could probably still be used, but they would have to be adapted to these new trends and technologies. For example, testing a "normal" user interface is very different from testing a groupware applications user interface, because apart from personal factors, social dynamics and politics also play a role in the success of groupware (Grudin, 1994b).

1.3.3 Support for communication within design teams
The aim of the last study described in this thesis was to develop recommendations on how to support communication. We studied one aspect of communication in more detail: the use of gestures in design meetings. Since we studied the use of gestures in one particular situation (e.g., one team size, one type of task, one type of background of participants, one type of culture) it is interesting to discuss whether our findings can be generalised to other situations.

We studied what gestures are used for what design meeting activities, to gain insight into how these activities should be supported. We studied the use of gestures during one specific task and with one specific team size. Furthermore, we studied the use of gestures during a relatively short task. Of course, everybody is experienced in using gestures, because we all use gestures in everyday life. However, the use of gestures may be affected the people communicating with each other. Although we only cover a very
small part of the total domain, our study indicates that both the available tools and the type of task (design versus procedure activities) affect the use of gestures. More research is needed to determine how gestures are used in other settings (e.g. other tools, other tasks, other team sizes, and more extensive tasks) and what the consequences are for the support of gestures.

Another factor that may affect how gestures are used is the cultural setting of the study. Differences have been found in the use of gestures by people from different cultures (Burgoon, 1985). For example, a study by Graham and Argyle (1975) showed that performance improved more for Italians than for English subjects when hand gestures were allowed to convey information on a spatial relations task.

These findings indicate that some cultures use gestures in different ways than others. However, it is unclear whether these cultures use gestures for the same activities, only more frequently, whether they use other types of gestures than those we studied, and whether they use gestures as a substitute for speech. Until more is known about the answers to these questions, it is hard to translate our findings on gestures in western cultures (e.g., European and North American cultures) into accurate information concerning gestures in other cultures.

One might wonder whether gestures actually contribute something significant to design communication. Why are speaking, drawing and writing not enough? To examine the importance of gestures, it is necessary to question whether the quality of the design, or of the design process, is influenced by the frequency and type of gestures that are used. However, since there are so many factors that affect the quality, it is hard to use such a general variable as a measure for the contribution of gestures. We propose alternatively that a local quality measure (instead of the quality of the final product of the design process) would be a fairer way of determining the benefits of gestures. In the following list we set down some of our ideas on local quality measures:

- The benefits to groups who use many and fewer kinetic gestures can be examined by determining which groups detect more errors in the user interface in an early phase of the design process.
- Another way in which the benefits of kinetic gestures can be analysed is by comparing the number of words (or total speaking time) used to explain concepts by teams that use many kinetic gestures, and teams that use fewer kinetic gestures.
• The value of point gestures can be studied by determining whether groups that use many point gestures (for reference) ask less frequently what is being referred to by a point gesture, than groups that use few point gestures.

Another question that needs examining is whether support for communication will be important in the future. In the future, teams will more frequently consist of people who work remotely. Supporting communication over a distance poses very challenging problems. Experiences with groupware in the past have revealed that communication protocols which work in face-to-face situations, cannot always be applied or do not always work when using CSCW tools. For instance, gestures that are used to organise turntaking in a face-to-face situation do not work when applied in video mediated communication (Heath and Luff, 1993). Supporting gestures through media such as video creates interesting problems. Apparently, gestures conveyed through video loose impact and do not trigger the same response as in a face-to-face situation. How such work should be supported, both in relation to what media to offer, and how structured the support should be has not yet been resolved (e.g., Olson, et al., 1995). We conclude that support for communication will also be needed in the future, and that the problems related to communication support have yet to be worked out.

1.4 Future research

User-interface design support
We indicated three areas for which improved support is needed: gathering information about users and their tasks, prototyping, and communication with people involved in the design project. We only studied one of these in more detail. The other two areas also need to be investigated further. Interesting questions in relation to these areas are: What are the main reasons that existing methods are not satisfactory?

Support for communication in design
We studied only one aspect of communication in design teams in more detail: the use of gestures in design meetings. The actions versus activities framework described in Chapter 5 gives an indication of further research that needs to be done. Examples of interesting research questions are: For which design meeting activities are the other types of actions (e.g. drawing and writing) used, and how is the design team’s behaviour (i.e. their choice of actions) influenced by the tools that they have available? These questions can be linked to questions concerning how people adapt their
behaviour to the available tools according to the principle of least collaborative effort (Clark and Brennan, 1989). It may be possible to predict how they will adapt based on the characteristics of each of the available actions (e.g. gesturing, speaking, writing and drawing).

Another interesting area for research is to determine how communication is affected by the fact that the team members have a different background. For example, examining whether they use different design techniques and different types of representations.

1.5 Conclusions

In short, we found that, because design practice is so diverse, it is hard to develop support that can be used by the complete set of design support users. Our research also indicated a number of areas for which design support can be improved: gathering information about users and applications, collaboration between people involved in the project (e.g., division of tasks and decision making), prototyping, and communication. We indicated the importance of studying communication as an activity layer over all other design activities, such as prototyping and recording the design process. This finding has major implications for how these design activities should be supported.

We studied communication within design teams in more detail. We developed a framework to study communication in such a way that support can be adjusted to the task (task-technology fit). We illustrated the use of the framework by studying the use of gestures by design teams. We found that communication support (for gestures) can be adjusted to the task and we offered recommendations on how to support communication within user-interface design teams.
2. **A tool-oriented analysis of user-interface design projects and the needs of designers**

2.1 **Introduction**

The aim of our research is to provide input for the development of design support (e.g., design methods or tools) for user interface design (see Figure 1.1). Before new methods or tools can be developed, we have to determine what design support is being used presently, and what new or improved support designers need.

Many design methods and tools have already been developed. However, previous research has shown that design support (design methods and tools) are not used as often as expected (Bellotti, 1990, Gould et al., 1991). It is apparent that the design methods and tools under the constraints in practice are difficult to apply, e.g., choosing the appropriate method for a particular design project can be difficult, and considerable time is required to get familiar with that new method (Grudin, 1994a, Bellotti 1990). To ensure that design methods and tools can be applied in practice, we need a better understanding of the context in which designers work. The well-known design principle "know thy user" applies also to the development of design support. Brown and Duguid (1994) expand on this principle in their paper on information technology design. They emphasise that not only the user, but also the design context (e.g. what is being designed and in what kind of project) should be understood. Therefore, we decided to conduct an analysis of design practice, analysing who the present users of design support are, and in what design contexts the support is being used.

Some information about user-interface design practice has been gathered in previous scientific studies. These studies of design practice have focused mainly on programmers and software engineers (Hammond, et al., 1983, Rosson et al., 1987), or large system design (Curtis et al., 1988). Since constraints may vary from project to project, we decided to look at a wide range of projects. In our study of design practice we therefore included both small and large projects and user interface designers from a variety of backgrounds.

To determine the nature of design practice we decided to question user interface designers about a wide range of topics. The questions were posed
in the form of a structured questionnaire (see Appendix 1). It was decided that interviews would be too time consuming and an observational study of design in practice too detailed.

In the present study we investigated who the prospective users of design support are, in what design context the support is being used, and what design support is needed to improve the design process. The study related to the prospective users of design methods and tools included questions on design experience and background. We included these questions because experience and background determine whether a designer has sufficient knowledge to be able to apply a design method (Bellotti, 1990). Questions related to design context included topics such as information sources that the designers consulted and the constraints that they experienced during a project. A constraint may be anything that impedes or prevents a design team from progressing in a manner what they perceive to be ideal towards their design goal (e.g., an oversized team). Information sources supply the knowledge that is consulted during a design project (e.g., literature, or observations of prospective users). The lists of constraints and information sources were adopted from a similar survey performed by Bellotti (1990).

We structured our questionnaire in such a way as to infer the designers' needs by combining the answers to several of the questions. Since they might feel that certain problems are inevitable in design practice, we did not ask them directly what these needs were. We inferred the need for tools from the answers to the questions about constraints and information sources. The answers to questions about designers, design processes, and methods were used to determine why it was difficult to apply design support in practice, and whether new or better design support could improve the design process.

In this chapter we describe the set-up of our study, the results of the questionnaire and we discuss what kind of design support is needed by designers.

2.2 Methods

We developed a questionnaire to gather information about the users of design support (user interface designers as defined in Chapter 1), about design projects and about designers' needs (see Appendix 1).
2.2.1 Respondents
Since no official association of 'user interface developers' has yet been created, it is not possible to list all the interface designers in the Netherlands. Our selection of respondents was therefore taken from informal networks, for example design researchers, employees of development companies, and Delft University of Technology graduates.

2.2.2 Questionnaire structure
To ensure that an accurate description of their experiences, and not a description of an ideal design project was captured, respondents were asked to base their answers on one particular design project that they had recently finished.

In the following section we list the information we wanted to gather and the related topics that were included in the questionnaire. We estimated that filling in the questionnaire would take approximately one hour.

The users of design methods and tools
This section of the questionnaire included questions about the background and experience of the designers. We wanted to get some idea of how much time was generally available for completing the associated design. We also included questions about the size of the team and the length of the project.

Design context
This section included questions on the following topics:
• The type of user interface being developed by the designers in the projects being described.
Since the complexity of the product to be developed can influence whether support is applicable or not, we were interested in the kind of user interface that was developed. Thus, we gathered information on the type of product or application, the type of input devices, and the interface styles.

• Design support used in practice.
Designers were asked to mention which of the following techniques were used in the project: specification techniques, formal design techniques, prototyping techniques or evaluation techniques.

• Information sources and constraints.
The questionnaire also contained questions on the information sources that designers consulted, and the constraints that they experienced during the project. The designers were asked to select items from a list
of information sources and a list of constraints. The list of constraints contained twenty-one items related to the methods used, the organisation of the project, the information available, the experience of the respondent, and the application. The list of information sources contained nineteen items, e.g., available literature, analysis of tasks and applications, interviews, observations and experiments.

2.2.3 Procedure
The questionnaire was sent to fifty user interface designers. After three weeks a reminder was sent to the designers who had not yet responded. A total of twenty-three of the fifty questionnaires were returned. Of the remaining twenty-seven designers, ten could not find the time to fill the questionnaire in. The reasons for non-response for the further outstanding seventeen are unknown.

2.2.4 Analysis
To facilitate the analysis we used multiple choice questions for as many topics as possible. We used open-ended questions in cases where the answers were hard to predict. For the questions on information sources and constraints, respondents had to select items from a list.

The number of times an option was chosen was counted for each multiple-choice question. The answers to the open-ended questions were assessed and classified. The items that were selected from the lists were ranked based on their frequency of selection.

2.3 Results
The questionnaire was used to gather information about the present users of design support, the design contexts in which the support was being used, and the designers' needs. Much of the information is quantitative, but we will also occasionally illustrate the results with comments given by the respondents. Table 2.1 gives an overview of a selection of the data.

2.3.1 The users of design support
Respondents' occupations varied from programmers, graphic and industrial designers to project managers and researchers. In terms of formal education the respondents had the following backgrounds: industrial design engineering (12), computer science (5), graphic design (2), psychology (2), physics (1) and electrical engineering (1). Experience in interface design varied from one to twenty-one years (median: four years).
Table 2.1
Overview of projects described in the questionnaires

<table>
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<tr>
<th>project</th>
<th>background</th>
<th>experience (in years) 1) 2)</th>
<th>product application</th>
<th>new or redesign</th>
<th>team size</th>
<th>project length (in years) 3) 4)</th>
<th>employment</th>
<th>users available</th>
<th># information sources 5) 6)</th>
<th># constraints 6)</th>
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<td>R</td>
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</table>

1) Ind. Des. = Industrial Design
Graph. = Graphic Design
Comp. Sc. = Computer Science
Psych. = Psychology
Electr. = Electrical Engineering
Phys. = Physics

2) • ≤ 1
   •> 1 and ≤ 3
   •> 3 and ≤ 5
   •> 5 and ≤ 10
   •> 10 and ≤ 25

3) Telecom. = Telecommunication System
   Office = Office System
   Info. = Information System
   Man. = Management System
   Graph. = Graphics System

4) • ≤ 0.5
   •> 0.5 and ≤ 1
   •> 1 and ≤ 3
   •> 3 and ≤ 5
   •> 5 and ≤ 10

5) University = University or research institute
   Comp. C. = Computer Company
   Non-Comp. = Non-computer comp.
   Freel. = Freelance

6) • ≤ 2
   •> 2 and ≤ 4
   •> 4 and ≤ 6
   •> 6 and ≤ 8
   •> 8 and ≤ 20
Comments from designers related to background and experience:
* One designer mentioned not having enough expertise to be able to use a cognitive walkthrough (i.e. a method used to evaluate user interfaces), she felt she had therefore missed an opportunity to gather information about the user.
* One designer explained that his prototype was not developed as extensively as proposed, because of the designer's lack of knowledge about programming.
* One designer mentioned that external software engineers had to be involved in the project, because of a lack of programming experience in the team.

2.3.2 Design context

Applications and products
Respondents were asked to describe the kind of application that was designed in the project described in the questionnaire.
A wide range of applications were described: telecommunication systems (8), management systems (6), information systems (5), graphics systems (2) and office systems (2). Twenty-two of the applications had a menu-driven interface, nine used form-fill techniques and six used graphic user interfaces with direct manipulation. As input devices seventeen applications used a keyboard, twelve applications used function keys, four used a mouse, three used a touch screen and one used a track ball.

Fourteen of the twenty-three applications were new, and nine of them were successors to an earlier version.

Design projects
Most of the designers worked for computer or software companies (8) and universities or research institutes (8). Four designers worked freelance and three worked for non-computer companies.

Team size varied from designers working alone (4) to designers working in a team of twelve. The median team size was four people.

Comments related to team size:
* Four designers stated that their team was too small, and that, as a consequence, not all the expertise needed for the project was available within the team.
Two designers stated that their team was too large, and that this resulted in problematic decision making and dissatisfaction with the assignment of tasks.

Four projects lasted only one month, whereas one project was completed only after eight years. The median project length was one year.

Comments related to project length:
* Five designers considered time pressure a constraint during the project.

**Design process**
Of the twenty-three designers thirteen were involved during the entire project, while ten respondents were involved during only a part of the project.

In ten of the projects specification techniques, such as task analysis or interaction grammars, were used. In eight of the projects formal design techniques, such as GOMS (Goals, Operations, Methods and Selection rules: a model of cognitive processes; Card et al., 1983) or JSD (Jackson System Development; Jackson, 1983), were used.

In twenty of the projects prototypes were made. The phases in which these prototypes were made ranged from very early to late in the project. In some cases only one prototype was made, whereas other respondents said they developed new prototypes after each iteration. The prototypes were used for the testing of ideas (e.g. response time), for usability testing and for presentations. In some cases the prototypes were used to communicate with the prospective users, whereas in other cases they were used to communicate with the clients.

Comments about prototyping tools:
* One designer said that prototyping tools were often of limited quality, because they have limited possibilities and low performance.
* One designer mentioned that building a prototype was so difficult it should have been done by an expert. Since such an expert was not available to her, the prototype was not as extensive as had originally been planned.

Evaluation techniques were used in sixteen projects. In ten of those projects users were involved in the evaluation of the user interface. In two projects experts conducted the evaluation, furthermore four respondents
conducted their interface evaluation with other people involved in the project (e.g. product manager and colleagues). In only nine cases was a specific evaluation technique described. Both formal user testing by actual users, and informal testing by colleagues were employed.

Constraints and information sources
Respondents could select as many items from the lists of constraints and information sources as they wanted. In this section, we list the top five constraints and the top five information sources. The range of constraints was zero to seven with a median of three. The range of information sources was zero to sixteen with a median of five.

Top five constraints selected:
• Twelve designers specified they had insufficient resources (time, money and equipment).
• Eight designers indicated that they had a lack of information about the user. Reasons that were given for the lack of information were lack of research, lack of information supplied by the marketing department, lack of time for testing, and changes in target user group half-way through the project.
• Seven designers identified that they had a lack of information about the application domain. First contact with a new application domain was mentioned most frequently as a reason for this constraint.
• "Complexity of the application" was specified by seven designers. Complexity was related to aspects such as managing the process, difficulty of developing user friendly products and the time necessary due to the project complexity.
• Five designers specified a lack of support by the marketing department. In other cases lack of support by management and lack of support by experts was mentioned.

Top five information sources selected:
• An analysis of similar applications was specified by sixteen designers. In some cases it was possible to analyse a similar product developed by a competitor, in other cases when a new product was developed, products that offered similar functions were studied.
• Ten designers identified "specification of activities" as their information source. The specification of activities is sometimes used as an aid in building an application or product.
• Interviews with prospective users was selected by nine designers
• Observations of activity using a prototype was given by nine designers.
Scientific literature (e.g. on human behaviour) was identified by nine designers. Some respondents mentioned that they had collected the literature during their education, while others mentioned the gathering of new information specifically for the project they were working on.

2.3.3 Support needed by the designers
The questions on the information sources applied and constraints experienced during the design projects were used to determine what kind of support designers might need and what requirements have to be met for the support to be useful in practice. The list of consulted information sources showed that the designers gathered information about users and similar applications. The list of constraints, however, indicated that they experienced constraints related to those very same aspects. Some of the reasons given for the fact that the methods and tools used to gather this information were not sufficient were:

- gathering information is too time consuming
- not all the expertise needed is available to the team
- the information simply is not available (i.e. it does not exist, for example, because of the novelty of the field)
- the importance of the information gathering methods and/or activity is not accepted by other members of the team, client or product manager
- the designer expected that some other party would supply information, but they failed to do so
- a lack of information about the user, because of changes halfway through the project or a vague description of the user
- infrequent contact with the users

If these reasons are taken into account whilst developing new or superior support for gathering information about users and applications then the design process itself can be improved. For example, by adapting the resources needed for using the support to the constraints of practice, and clearly explaining what the support’s costs and benefits are.

2.4 Discussion

We used a questionnaire to gather information about design practice. We asked user interface designers to describe their experiences during one recently finished design project. In this way, we gained useful insights into who the users of design support are, and in what design context the support is being used.
Since response was voluntary, it is hard to determine whether the responses are representative of design practice in general. It is possible that the designers who responded experience more constraints or are more interested in design methods than the average designer. However, since many of the possible working environments (software companies, non-computer companies, free-lance designers and research institutes) are represented in this survey, the results give a broad overview of design practice in the Netherlands.

2.4.1 Users of design support and design context
Some designers work alone and on very short projects, while others work in large teams and on projects for many years. The constraints experienced also varied considerably, depending on, amongst other things, the time and expertise available to the team. Some designers hardly experience any constraints, whereas others experience many constraints. The results show that users of design support and the contexts in which such support has to be used differ extensively. Rosson et al. (1987) and Hannigan and Herring (1987) also found that design practice was very diverse. The background of the subjects in their studies, the team sizes, and the country in which the projects took place, however, were different from our investigation.

Consequently, this means that design practice is much more varied than described in the separate studies of Rosson et al. (1987), Hannigan and Herring (1987) and our study.

The information we gathered about the present users of design support can be used by design support developers: when they take into account who the potential users of their support will be, it may be possible to improve its applicability. Based on the descriptions of design practice such as in this paper and those by Rosson et al. (1987), Curtis et al. (1988) and Hannigan and Herring (1987) developers can determine for what potential users they can develop design support (e.g., a specific selection, or the entire user interface design community). Design support developers have to decide whether they think it is feasible to develop support for design practice in general, or how to select some part of it when they choose their target users.

2.4.2 Designers' needs
We were specifically interested in what design support is needed by user interface designers. We identified two areas for which design support could be improved and developed: gathering information about users, and
applications. Even though designers gather information about users and applications, they are constrained from obtaining sufficient and suitable information.

Whether design support is or will be applicable to a particular design situation depends on a number of factors. We listed a number of reasons for the fact that present methods and tools were not used in some projects. One of the reasons given was that designers often feel they do not have enough resources to develop the system in the way they want to. This overall constraint is similar to those found in other studies (Bellotti, 1990 and Rosson et al., 1987). Other reasons that were mentioned were: whether the support could be applied to the user-interface style of the application and whether the results could be communicated to the other team members. An example of how design situations can affect the applicability of a design method is described in Vermeeren and Bekker (1993). They describe two different design situations and how these affect which evaluation method can best be used in each situation.

Based on our results developers of design support have information on how to improve their support. The results also provide information about the prospective users of design support. This can aid support developers in understanding whether the support will be easy to use in practice.

A problem related to developing applicable design support, is to ensure that designers choose the appropriate support for their design situation. A method or tool that is applicable in one type of design situation, may be hard to apply in another situation. Choosing the appropriate support is difficult for designers, because the literature is not organised to give an easy overview of methods and tools (Olson and Moran, 1995). In some situations, for example, had the designers known there were other methods that would have been more suitable considering their time constraints, they could have adopted them.

To aid design teams in choosing the appropriate design support for their design situation, overviews and checklists of design support should be made. For example, for usability-evaluation methods a preliminary taxonomy has been proposed (Hix et al., 1994). Other checklists that assist designers in choosing the appropriate evaluation method have been described in Vermeeren and Bekker (1993) and Olson and Moran (1995). These efforts should be expanded to other types of design support.
2.4.3 Future research
In the present study we determined that designers need better support to
gather information about users and applications, and more information on
how to choose the appropriate design support. In the next chapter
designers were interviewed about their experience in practice. In this way
we can determine how design methods or tools can support designers
effectively under the constraints of the real world.
3. Problems occurring in design practice and their relevance for user-interface design support

3.1 Introduction

The functionality of products, and computer applications are becoming more advanced, in turn, if the increased functionality is to be exploited good user interfaces are a necessity. The importance of designing good user interfaces for products and applications is being recognised by more and more manufacturers. However, developing a good user interface is difficult. It is difficult for two reasons, firstly, because user interface design is a new field and knowledge of many fields, such as psychology, computer science, design and ergonomics, have to be integrated and secondly, because new design possibilities are becoming available due to rapid advances in technology, e.g. virtual reality and multi-media.

We are interested in what kind of support is needed by user interface designers to improve the design process. Many tools and methods are already available. However, they are not used as often as expected (Gould and Lewis, 1985; Bellotti, 1990). An important reason why support is not used is that designers in practice do not always have enough time and experience to use the methods and tools efficiently (Grudin, 1994a; Bellotti, 1990). Another reason that we mentioned in Chapter 2 was that it is difficult for designers to find a comprehensive overview of the available design methods and tools, and thus to choose the method or tool most appropriate to their situation.

A previous study (Bekker and Vermeeren, 1992) showed that there are areas for which support can be improved. That study indicated two areas for which support would be useful: gathering information about the tasks and working environment of users, and gathering information about the applications. In this chapter we describe a follow-up study. We interviewed designers, some individually and some in groups. We asked them to describe their experiences based on a project that they had recently finished. We determined what problems designers experience in design projects, and what kind of support the designers felt could (partly) solve some of those problems, and thus improve the design process.
The general topics that we selected to be discussed in the interviews were based on the constraints that were mentioned most often in previous research (Bekker and Vermeeren, 1992): the collaboration of people involved in the project, task division and decision making, gathering information about users, gathering information about the application domain, and availability of resources.

Our findings show that support is needed for prototyping and communication with people involved in the design project. Furthermore, a more detailed analysis of the communication problems resulted in a preliminary list of recommendations for communication support.

3.2 Methods

We used interviews as a method of investigation, as they are flexible and adaptable to an individual’s situation. They also allow the researcher to probe for further explanations to the answers given to questions (Kerlinger, 1986). Although there is less uniformity when questions are posed verbally than when using a questionnaire, it is easier to detect misunderstandings. An interview schedule was developed containing questions about various aspects of design projects. We used a semi-structured interview. All questions were open-ended and the order of the questions was fixed. Depending upon the answers of the subjects, the interviewer decided whether follow-up questions were necessary.

We used both solo and group interviews. The solo interviews provided the chance to gather more detailed information about the designers’ experiences during the projects described in the interviews, whereas the group discussions were used to determine whether designers recognised each others’ experiences. The solo interviews were held at the workplace of the designers, and the group discussions were held in our laboratory. During the solo interviews one researcher asked the main questions, while the other researcher monitored the interview and sometimes suggested interesting topics that could be discussed in more detail. During the group sessions the person who monitored the interview was located in another room. He followed the interview on a screen and could advise the interviewer through the use of a microphone and ear piece.

All interviews were recorded on videotape for further analysis.
3.2.1 Subjects
Eight designers participated in the solo interviews, and eight others participated in the two group discussions. Most subjects worked for a software or computer company (5) or as a freelance designer (5). Three subjects worked for a non-computer company and three worked in a research institute. Their positions varied from programmer (2), graphic designer (2), and product or interface designer (10) to project manager (2).

3.2.2 Set-up of interview
Five topics were selected to be discussed in the interviews: collaboration of people working on the project, task division and decision making, gathering information about users, gathering information about the application domain, and availability of resources.

To ensure that the designers would not describe an ideal project, we asked them to base their answers on one specific project that they had recently finished.

The interview consisted of three parts:

1) In the first part of the interview the designer was asked some background information about the project that was going to be discussed (e.g. team size, type of product, project length).

2) In the second part the following topics were discussed:
   - people involved in the project, e.g. number of people (outside of team), people's background, position of the person(s) involved in the project (e.g. user interface designer, advisor, consultant) and type of information exchanged
   - collaboration within the team, e.g. decision making process and who was responsible for what part of the design
   - gathering information about users, e.g. knowledge of target users, available information and information sources
   - gathering information about application domain, e.g. available information and information sources
   In this way we inferred the needs of the designers.

3) In the third part of the interview subjects were asked to describe with what kind of tools they thought the design process could be improved.

Since in some cases subjects felt problems were inevitable and therefore refrained from mentioning them, we decided not to ask subjects about their problems explicitly. Instead, subjects were asked to describe what their
experiences were, whether they were satisfied during the project and whether they had had different experiences in other projects. Based on this information we determined what problems could be (partly) solved by offering new or improved design support. We also asked them what tools they believed they would need to improve the design process. The complete interview is included in Appendix 2.

3.2.3 Procedure
Each subject was telephoned and asked whether they were willing to participate in the experiment. The subjects that agreed gave their permission for the interview to be videotaped. Subsequently, they received a letter confirming the appointment.

The interview itself started with an introduction by the interviewer in which the purpose of the interview, its confidentiality and anonymity were explained. Each interview took approximately ninety minutes.

3.2.4 Analysis
Transcripts were made of all videotapes. The transcripts were scanned for problems referring to designers' needs for design methods or tools. We were interested in who was involved in the problems that arose during the projects. Therefore we determined at which behavioural level (see Figure 3.1) the problems occurred. We distinguished between problems at the individual level (the designer himself), at the team level (the designer and his team members), and the project and company level (the designer and project managers or higher management) (Curtis et al., 1988).

We were also interested in whether a problem only occurs during one type of activity, e.g. while making prototypes, or whether it occurs more generally. Thus, the problems were also categorised according to activities during the design project: information gathering about users and tasks, generating ideas, prototyping, evaluating and implementing the design. The design process can be described as a sequence of these activities; the activities can be revisited in a cyclic process, until the final product or application is realised.

The number of designers that mentioned a particular problem gave an indication of how widely a problem was experienced. The number of activities during which the problem was experienced indicated whether it was problem specific to a given activity or a more general problem.
The layered behavioural model of user interface development. The first level refers to the user interface designer, the next level to the team in which the designer works, and the third level in our analysis refers to the project and company in which the designer works (adapted from Curtis et al., 1988).

During the last part of the interview the designers described with what kind of support the design process could be improved. We categorised the support according to its purpose. While describing the type of design support, designers often mentioned requirements that would have to be met by these types of support. These requirements were also listed.

In order to gain a more thorough understanding of the activities that would have to be supported, the data was scanned for remarks that explained in more detail in what context the problems occurred.

3.3 Results

First, a brief overview of the answers to the interview questions is given, to present an impression of the design projects described. Then we discuss the problems mentioned by the subjects and the tools needed by the designers. Following that the kind of support needed by designers, based on the information on problems and tools is determined. Finally, we elaborate on the reasons that were given for the most frequent problems that occurred.
3.3.1 Comments of the user interface designers

3.3.1.1 Descriptions of the design projects
Below an overview is given of the answers to the questions related to the background information of the design projects and the five topics that were discussed in the interview.

Team size varied from three to thirty members with a median of six people. A wide variety of applications and products were described, including telecommunication applications (e.g., a business telephone), point of information systems (e.g. a museum information system), consumer products (e.g. video equipment), and process-control information systems. The shortest project lasted one month, and the longest three years (median of eighteen months).

People involved in the project
The team usually consisted of a project leader, one or more user interface designers, and one or more programmers or software engineers. Depending on the type of project and the expertise needed, one or more experts (e.g. ergonomists, psychologists or technical experts) were included in the team.

People from outside the team were consulted for further, necessary, information:
• Ergonomists, clients, users and sales organisations were consulted on information concerning prospective users.
• Other design companies and informal networks, consisting of colleagues and friends were consulted about the designs in general.
• Suppliers of hard- and software and programmers were consulted about hardware and software issues.

In some cases people were paid for their advise, while in other cases the communication was more informal.

Collaboration within the team
The way collaboration within the team was organised depended, among other things, on the number of parties and / or companies involved, the amount of overlap in expertise in the team and the management style of the project manager. In some projects tasks were not clearly defined and unnecessary delays were incurred due to the ensuing lengthy discussions. In some projects collaboration was hindered because team members used different design methods.
Figure 3.2
An overview of whether designers, team members (other than designers), clients and users are situated in the same, or in separate companies and the number of projects for each of the situations. A represents projects where all the people involved work for the same company. B represents projects where the user does not work for the same company as the designers, the team members, and the client. C, and D represent projects where the designer and the team work for the same company. In E only the client and the user reside in the same company, and in F all the people work for different companies. The circles represent the designers (d), the triangles represent the team (t), the diamonds represent the clients (c), and the squares the users (u). The boxes indicate who belong to the same company.

The people involved in the projects were sometimes working for the same company, but in other cases they were located in as many as four different companies. Figure 3.2 gives an overview of whether the designers, team members (other than designers), clients and users were situated in the
same, or in separate companies, and the number of projects of each of the situations that were included in the study. When people work in the same company contact between those people is easier and it is more likely that they use the same design methods than when they work for different companies.

Gathering information about users
In some cases designers had direct access to users to gather information. In other instances designers had to get information through sales organisations, user representatives and clients. In the case of in-house development it is generally easier to gather information from the user directly than in the case of off-the-shelf development (Grudin, 1991). In the latter, information usually has to be gathered through intermediaries.

Gathering information about applications
The following people were consulted to supply information about the application domain: clients, colleagues, users and suppliers. Other sources tapped were conferences, literature and video's from conferences and analyses of other applications (from competitors).

3.3.1.2 Problems experienced by designers
While describing the design projects, subjects mentioned many problems they experienced during their work. We used two dimensions to classify the problems into groups: the activities during which the problems had occurred, and the behavioural level (individual, team, and project or organisational level) at which they had occurred. Table 3.1 gives an overview of the problems expressed by the designers according to the types of activity and behavioural level.

Problems classified according to types of activity
Some problems were very specific for a particular activity, such as the problem of how to make simulations. Other problems occurred throughout the entire design process, especially those problems concerning communication about design solutions and involving the users.
Table 3.1
An overview of the number of designers that mentioned a problem, according to behavioural level (in columns) and type of activity (in rows). D = number of designers that mentioned a problem. The three behavioural levels are: the individual level (designer), the team level and the project and organisational level. Since one designer may have mentioned the same problem for more than one cell, the number of designers who mentioned a problem does not add up over the number of cells. The two problems that were mentioned most frequently were: Communication problems (underlined), and problems related to user involvement (in italic).

<table>
<thead>
<tr>
<th>Behavioural level</th>
<th>Designer</th>
<th>Team</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>how to organise the design process</td>
<td>3</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>representing users</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>how to use tools/methods</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td>Analysis</td>
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</tr>
<tr>
<td>lack of technical information</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>lack of information about users</td>
<td>3</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Idea Generation</td>
<td></td>
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<td></td>
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<tr>
<td>representing the users</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>how to organise idea generation</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>how to organise the design process</td>
<td>4</td>
<td>9</td>
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<tr>
<td>Simulation</td>
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</tr>
<tr>
<td>making simulations</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Evaluation</td>
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<td>what to evaluate</td>
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<td>how to evaluate</td>
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<tr>
<td>Implementation</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
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<tr>
<td>communication about design solutions</td>
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</tbody>
</table>
Problems classified according to behavioural level
Problems at the individual level were related to whether the designer had knowledge or access to knowledge that was relevant for the design project. The problems were mostly related to how to apply design methods and how to represent users. At the team level, problems related to communication were often mentioned. At the organisational level, communication problems and problems involving users were mentioned frequently.

The following two types of problems were mentioned most frequently, they occurred during many activities and at many behavioural levels (see Table 3.1):
• communication with team members, clients and other people involved in the project (eleven out of sixteen subjects).
• involvement of users in the design project and gathering information about their tasks (ten subjects).

3.3.1.3 Tools and requirements
Below an overview of the tools and requirements that designers mentioned when they were asked how the design process could be improved is given.

• Prototyping tools (9 designers)
  Many prototyping tools are already available, but the designers felt that they should be improved. The tools should be easy to use. They should also make it possible to make prototypes quickly and interactively with other people involved in the design process.

• Communication facilitating tools (6 designers)
  Designers felt the need for tools that would support communication with other people involved in the project. Such tools could support developing a collective terminology. They could also support adapting information to specific communication partners, e.g. relevant information for the programmer may not be relevant information for the ergonomist.

• User involvement tools (5 designers)
  Such tools could offer support in helping to decide how users should be involved in the design project and how results of user tests should be evaluated.

• Project management tools (4 designers)
  Project management tools could support storing and managing documents which are used during the design project.
• Decision support tools (4 designers)
  Such tools could help gather and present information as support for design decisions.
• Interface description tools (3 designers)
  The relations between design decisions and solutions could be usefully documented with interface description tools. Such tools could aid designers in keeping track of consistency and relations between design decisions.

3.3.1.4 Conclusions based on problems and tools mentioned by designers
Three problem areas follow from the table of problems and the list of tools: communication, prototyping and user involvement. To decide what problem to study in more detail, we determined what problem was mentioned most frequently both in the experiences described by the designers (inferred needs), and in the list of tools (explicitly mentioned needs). Furthermore, we needed to select a problem to study in more detail that could be solved by offering better support. Some of the problems were important, but offering better tools would not be the best way to solve those problems. For example, in some cases the design process was hard to organise because people from different companies did not agree on what design methodology to use, and not because the design methodologies needed improving. The information on problems occurring during the projects, and tools needed to improve the design process both indicate that designers need support for communication activities. Because communication covers almost all other design activities (such as prototyping and user involvement), and because we felt that the problem could be partly solved by developing better support, we decided to study it in more detail.

3.3.2 Communication problems in design projects
To increase our understanding of the contexts in which communication problems occur, an extra analysis of the transcripts was performed. Below is a list of some of the reasons that were given for the communication problems, illustrated with quotes from the transcripts. Some problems were related to the people involved in the design projects, while other problems were related to the representations and tools used to make these representations.

Problems related to the people involved in the project:
Three designers stated that people belonging to different disciplines used different terminology and different types of representations during the design process.
Comments:

- "People in the team do not always understand each other, and this is partly caused by the fact that they do not speak each others language. You think you are talking about the same thing, but after a while you find out this is not the case."
- "It is very hard to gather technical information, because everybody uses different terminology."
- "I always have to write things down or explain them to translate them from my way of talking to their way of talking."

Two designers mentioned that when teams are large, everybody in the team wants to have a chance to voice their opinion, and thus communication takes a lot of time.

Comments:

- "At first everybody would meet once a week to discuss progress. Later on we met in a smaller group, because meetings were difficult with such a big team."
- "You have to convince other people of your ideas. When I work in smaller projects communication is easier: I write a specification of the user interface and then it is built that way."

Two designers stated that they felt that team members did not meet frequently enough. In such cases team members may interpret decisions made in different ways, and the misunderstandings that follow can be time consuming. One of the reasons why teams do not meet frequently, is that team members work for different companies, and they are situated in different locations. In such cases they miss the opportunity for informal meetings on coffee and lunch breaks, etc.

Comment:

- "Choices have been made that should not have been made. In some cases this is not discovered until a couple of weeks later."

Problems related to the use of tools and representations (e.g. drawings and prototypes):

Two designers pointed out that it should be easy to make changes in representations (e.g. drawings and prototypes), while discussing a design solution with somebody. The final representation is important, but the process of making the representation and being able to change it as a result of comments must be considered.

Comments:

- "It is not possible to alter it together with the person sitting next to you. You have to go away, change it, and come back with the new representation."
• "We prefer using portable white boards, with paper on them, everybody gets a Xerox of the results. Generate design solutions together with other people. Make drawings. Everybody contributes something."

Two designers mentioned that they do not always have time to learn to use new tools.

Comments:
• "In a similar project, they wanted to make a simulation. But they didn’t do it, because it would have take too much time to learn to use the prototyping tool."
• "We have a new computer and some prototyping tools, but have not had the time, yet, to learn to work with them."

Four designers stated that the level of detail in a representation affects the way that communication partners perceive the representations.

Comments:
• "When you confront them with a story board (i.e. sequences of snapshots which focus on the main actions in a possible situation) you get many comments. When you confront them with a complete working system you get comments on a much more detailed level. It depends on the level of detail that you offer."
• "State diagrams are too precise and they seduce people to linking more and more states for afternoons on end."
• "The quality of the representations determines the status: if it looks too good, they think it is a more definitive version of the design."

One designer mentioned that the tools used to make these representations, e.g., drawings and prototypes, are not flexible enough. It should be possible to switch easily between making rough sketches and more formal drawings.

Comments:
• "I want to be able to create representations quickly, and switch easily between making a rough sketch a more detailed drawing."

Three designers felt that representations should be reusable.

Comments:
• "I determine how I have to do it, so I can reuse it later in the project."
• "It should be possible to keep on using it, when you are making sketches but also when you are working on a more detailed level."
Two designers wanted to use an account of the design process captured in representations to reconsider design decisions.

Comments:
- "It's like a puzzle. You think of a solution, but the solution is no good. You think of another one, also no good. When you think of the tenth solution, you've forgotten why solution number three was no good."
- "Video is a powerful medium. You want to keep the raw data, but you also want a summary of the data. That is difficult to realise."

3.4 Discussion

Previous research undertaken as part of this thesis suggested that designers need support for gathering information about users and applications (Bekker and Vermeeren, 1992). For the study described in this chapter sixteen designers were interviewed to determine what support is needed for these activities. Since a list of all user interface designers in the Netherlands did not exist, it was not possible to select the subjects randomly. However, we selected subjects and projects from a wide range of companies to ensure that we gained as broad, and representative a view of design practice, as possible.

Because subjects in the solo interviews had relatively more time to explain things than the subjects in the group interviews, the solo interviews offered more detailed information about the design projects being described. The participants in the group interviews could in some cases relate to the experiences of other participants. In other cases designers were surprised to hear the experiences of other participants; some designers felt their projects were of such a different nature that it was hard to compare them with the projects of the other participating designers. Even though the amount and depth of information collected in the solo and the group interviews differed, we treated the data of the solo and the group interviews in a similar way. The difference between the information of the solo and the group interviews may have lead to the over-representation of some comments, because designers in the group interviews sometimes confirmed each others ideas. Furthermore, we had less detailed information with which to interpret the answers of the designers in the group discussions than in the solo interviews. However, the problems and tools were mentioned during many of the interviews by designers who worked in diverse design contexts, so we consider our findings to be legitimate.
3.4.1 Designers' needs
We were interested in the kind of support that designers felt could improve the design process. The tools that were mentioned most often when designers were asked how the design process could be improved were communication tools, and tools used to describe the design, such as prototyping tools. A problem that was pointed out frequently by the designers was communication problems with people involved in the project. Another problem, which was also found in the previous study (see Chapter 2), that was often mentioned was involving users in the design process.

The three areas for which improved tools are needed are highly related; designers communicate with various people, including users, using various representations, such as prototypes. Another related problem that was found in Chapter 2, was the difficulty of choosing the appropriate methods and tools for these activities, because design projects are so varied.

We studied one of the areas in more detail. We selected communication problems, because they were mentioned by many designers, both when describing their experiences, and when explicitly asked how the design process could be improved. We conducted a more detailed analysis of the interview data to study the contexts of communication problems (3.3.2 Communication problems in design projects).

Communication problems were found not only in user-interface design practice (Rosson et al., 1988), but also in systems (Curtis et al., 1988) and product design practice (Ancona and Caldwell, 1990). Rosson et al. (1988) describe an analysis of user-interface design practice. They focused mainly on design tools for specific activities, such as prototyping and idea generation, however, communication is mentioned as part of these activities. In a study of system design practice by Curtis et al. (1988) breakdowns in communication and coordination were found to be one of the three most salient problems. They described, amongst other things, the importance of support for informal networks and the documentation of design rationale. Ancona and Caldwell, (1990) analysed the tasks of product teams to determine how information technology might support product teams. They found that each phase of the design process asks for different patterns of team functioning and different patterns of interaction with outsiders. For example, in the idea generation phase, teams need tools that help to keep an overview of agreement and disagreement. Conversely, in the actual development phase, the emphasis should be on keeping track of progress and schedules with the aid of scheduling tools.
These studies (Rosson et al., 1988, Curtis et al., 1988) also conclude that communication support in design projects needs to be improved. However, they present communication as a separate activity during design projects. An important result of our study is that communication is not so much a separate activity, as an activity-layer over many other design activities. Members of the design team have to write reports, make drawings, build prototypes, set-up a user test, and during all these activities they communicate to other people involved in the project. Thus, although special purpose communication tools, such as e-mail, are certainly important, support for communication while working on another activity is often overlooked. For example, prototyping tools are developed so that prototypes can easily be build. However, the need for special functionality for communication, for example so that quick changes can be made, while the prototype is being discussed with other team members, is often neglected. An important result of our study is that support for design activities, such as prototyping, has to be developed with communication in mind.

3.4.2 Communication problems
Our additional analysis produced some insights into why communication problems occurred. Some problems were related to the communication partners with which design ideas had to be discussed, whereas other problems were related to the use of representations and tools.

Below an overview of communication problems, based on a large number of real-life cases is given. We did find examples of communication problems in papers describing personal experiences of one, or two designers in user interface and related design fields, however, usually the papers on personal experiences only touch upon one, or two communication problems. We feel that our findings are especially interesting, because they are based on many cases in different types of projects, whereas the papers describing one person’s experiences are usually based on one type of project. Furthermore, we give a list of recommendations on how to support communication based on our findings.

Differences in communication between disciplines
Other designers describing their experiences in the literature have also mentioned problems being related to the communication partners. In his article on interdisciplinary cooperation in user interface design Kim (1990) explains that people from different disciplines have different priorities,
different thinking styles, and different values. When people from different disciplines work together, the differences in priority can lead to misunderstandings. Minneman (1991) also found that engineering design groups from various divisions (engineering, manufacturing and marketing) express their ideas in different ways.

*Interactively making representations*
During the interviews designers mentioned that the process of making the representations is as important as the final representation. They mentioned that interactively making representations with other people involved in the project is not well supported at present. In the literature a number of examples can be found that illustrate this. Wulff et al. (1990) report on the use of animating interfaces (a prototyping and simulation technique in which a group of people collaborate in the process of visualising the interface) as a valuable technique for interface design. This technique explicitly uses the prototyping technique as a means of transferring knowledge to all people involved in the design process. They state that the scenarios or enactments of the participants are more important than the final prototype or representation itself. Vertelney and Booker (1990) discuss the applicability of industrial (product) design techniques to the design of user interfaces. They explain that sketching ideas while clients describe what they want, can help clarifying design objectives even at an early stage of the product's design.

*Level of detail in representations*
Four out of sixteen designers mentioned that the level of detail of design representations affects the way that communication partners perceive the representations. They mentioned that the tools they used did not always allow them to choose the appropriate level of detail. A design solution is perceived to be more definitive when a representation is more detailed than when it is only a rough sketch.

Wong (1992) describes the merits of using graphic design techniques for user interface design. She explains that the level of detail affects the level of design questions that are addressed by user-interface design teams. Rough sketches are used to elicit high level critique and detailed graphics are used to elicit critique on details.

*Capturing the evolution and an account of the design process.*
The descriptions of design projects in practice show that (parts of) representations are reused. Three designers stated that they reused representations in later phases of the design project. Wagner (1990)
describes what her "perfect world" would look like, if she had the "perfect" prototyping tools. She points out that, with today's tools, she cannot go back and reuse portions of a drawing, once she has drawn an idea for a user interface on paper. For fast and easy iterative design being able to reuse representations is required.

Designers also mentioned in the interviews, that they used an account of the design process, captured in design representations, to reconsider design decisions. This is an issue that is also recognised by developers of representation techniques for design rationale, e.g., MacLean et al. (1991). Minneman (1991) also mentions the need for a revisitatable record of design negotiations. His ideas are based on a study of a number of design workshops and on a longitudinal study of a design project in an industrial setting.

In short, our findings indicate a number of areas that communication tools should support: communication between people from different disciplines, and the use of representations and tools for communication purposes.

3.5 Conclusions

We conclude that designers need improved support for 1) involving users in design projects and gathering information about the users' task, 2) prototyping and 3) communication activities. We selected communication activities, as that was mentioned most frequently, to study in more detail. Communication plays such an important role throughout the entire design process and during so many related activities, that support for communication about all these activities deserves to receive more attention. We stress the importance of looking at communication as an activity that is a layer over other activities, and that tools for activities, such as drawing, writing reports, and building prototypes should offer extra functionality to facilitate communication.

Most communication problems were related to the use of representations and the tools that are used to make the representations. Representations play an important role in interface design, since they contain the description of the design at a particular moment in time, and are constantly modified and used for reference purposes. Based on the results of our study we list some preliminary recommendations for a communication tool:
- representations should be reusable
• it should be flexible in level of detail
• it should allow you to switch between making rough sketches and more complete drawings
• it should make it easy to change a representation quickly
• it should allow the possibility to collaborate with other people involved in the design process during the process of making representations
• it should permit capturing an account of, and the reasons for, design decisions in the representations
• the tool should be easy to learn
• it should be possible to adjust what parts of the representation are to be emphasised depending on what information needs to be conveyed to the communication partner
• support for communication with people from other disciplines should be available (e.g., terminology and types of representations)
4. The use of actions on representations in design meetings

4.1 Introduction

The study in Chapter 3 showed that better support is needed for communication, and more specifically for communication about representations (e.g. documents, drawings and prototypes) of design ideas. Representations are used to discuss design ideas with other people involved in the design process.

In this chapter we describe an exploratory study we conducted on the use of representations in design meetings. The purpose of the study was to test qualitative and quantitative methods for analysing design in order to come up with recommendations on how to support communication in design teams.

Other researchers who have studied the use of actions on representations in design meetings include Tang (1989 and 1991) and Bly (1988). They both studied what actions designers use to discuss user-interface design problems. Both quantitative and qualitative analysis were used in their studies. Inspired by their work, we examined how to use quantitative and qualitative ways of analysing behaviour to gain experience in how to study the behaviour of design teams. We used a qualitative analysis to determine for what purposes representations were used, what roles people played in the meeting, and whether the representations were shared, or used privately. This analysis was inspired by interaction analysis (Jordan and Henderson, 1992) and ethnographic studies (Agar, 1985). We used a quantitative analysis, similar to the one used by Tang (1988, 1989), to study what actions were performed on the representations.

In this chapter we will focus only on the quantitative analysis, because these findings have been most influential on the approach for the rest of the research described in this thesis.

4.2 Methods

To determine what actions were used for communication we analysed the data of three groups that worked on a redesign task in a laboratory setting.
We decided to conduct the study in the laboratory, because we wanted to
gather comparable data from three groups working on the same task, for
the same period of time.

4.2.1 Subjects
For the sake of comparability of design tasks and accessibility of subjects
we used industrial design students. We studied three groups of students
(two groups consisted of four students, and one of five) in their third or
fourth year, who had previous experience working together as a group.

4.2.2 Procedure
The students were asked to make a redesign of the user interface of a
telephone answering machine. They were given the results of a user-test
conducted by another group of industrial design students as part of their
Human Factors course. The results of the user-test consisted of a list of
problems which had occurred when users tried to use the telephone
answering machine. The subjects were also given the telephone answering
machine and its manual.

They worked on the task during two sessions of one and a half hours each.
Between these two sessions the subjects were asked to work on their design
ideas for one hour at home.

Video recordings were made of all sessions in the laboratory. Two views
were recorded: an overview of the table and the subjects, and a close-up of
the workspace on the table.

4.2.3 Coding actions
We were interested in what actions were performed on the representations
(e.g. drawings, documents and products) by the design teams. First, we
studied one hour of industrial design students working on the redesign of a
user interface (the exercise was a part of a human factors course) to
determine what actions were performed on representations. Based on this
analysis the following actions were included in the coding scheme:
• editing, including all changes made to representations (e.g.,
drawing and writing)
• pointing, including all pointing gestures made; both pointing
gestures specifically directed at some part of a representation and
gestures directed to no part of a representation in particular (sometimes
made above the table instead of at a particular representation)
The use of actions on representations in design meetings

- moving, including all movements of representations on and above the workspace, such as moving over the workspace and picking up and laying down a representation
- looking, including only the cases in which subjects take notice of a representation, but do not conduct any of the other three actions on the representations. This action is included in the coding scheme to ensure that representations on which no actions are conducted, but that are used as a reference or inspiration source, are included in the description of the design teams' behaviour

Second, we decided how to code the actions. We considered using a fixed amount of seconds as a unit of analysis for coding the actions. However, since some actions last for many seconds (e.g. editing), and others take only a fraction of a second (e.g. pointing) we decided against it.

The coding scheme was used to describe situations in the meeting and transitions in situations. For each situation we described how many people were working simultaneously, how many representations were being used, and what kind of actions were being conducted.

A transition between situations occurred when:
1) a subject changed from conducting one type of action to another type of action
2) a subject changed from conducting an action on one representation to another representation
3) a subject started or stopped with one or more actions
4) a subject performed a combination of the above

Verbal activity and non-verbal behaviour which was not directly related to the representations, such as sitting back in one's chair, was not included in the scheme.

4.2.4 Analysis
Because of time constraints we decided to code only a selection of the videotapes. We wanted to compare the use of actions for two different tasks. Therefore, we selected to analyse the first half hour of the second session in which the groups presented their design ideas to each other, and the last half hour of the second session in which the groups prepared a short presentation of the final design.

For each group, during the first and in the last half hour of the second session, we determined how often they used the four types of actions.
4.3 Results

4.3.1 Frequency of occurrence of actions
Since the total number of actions varied greatly between the three groups we calculated the percentage of actions for each of the groups. For each group we determined how many actions (edit, point, move and look) were used during the first and the last half hour of the second session. Figure 4.1 gives an overview of the percentage of actions for each of the groups (the open symbols represent the first half hour and the closed symbols represent the last half hour of the second session). On average the groups used 261 actions, with an average of 28 edit, 126 point, 84 move and 23 look actions during the first half hour, and 651 actions, with an average of 369 edit, 85 point, 164 move and 33 look actions during the last half hour of the second session.

The figure shows that groups use mostly point actions when they present their ideas, whereas they use mostly edit activities when they are sketching the final concept.

![Figure 4.1](image)

*Figure 4.1*
An overview of the occurrence of the various actions (edit, point, move and look) that were used by the three groups during the first half hour of the second session (explaining design ideas in the group: open symbols), and the last half hour of the second session (sketching the final design: black symbols). Note that the lines in this figure have no meaning apart from grouping symbols of the same set.
4.4 Discussion

We studied what actions three groups of industrial design students used on representations.

4.4.1 The use of actions
We compared how the three groups used actions (point, edit, move and look) for two different tasks (presenting design ideas and sketching the final concept). Representations were used all the time, ranging from sketches to more final drawings. Subjects constantly switched between conducting actions on representations and actions not directly related to representations. However, often the actions not directly performed on the representation explained some aspect of it. They made the representations together, changing their level of detail and capturing some of what they were discussing. For some explanations subjects used permanent actions, such as drawing and writing, but for other explanations they used ephemeral actions such as gesturing.

We found that the groups used mostly point actions for presenting design ideas (> 50 %), whereas they used mostly edit actions for sketching of the final concept (> 50 %). This indicates that even though the actual number of gestures that each group uses differs, it is possible to find a relation between the actions that are used and types of tasks that are being performed. Such relations could be used to adjust communication support to the type of task that is to be supported. For example, developers could take into account when deciding what technology to choose, whether a technology is appropriate for supporting the actions most frequently used for a specific task.

4.4.2 Evaluation of the study
We coded point, edit, move and look actions. Coding the "look" action was especially difficult to code consistently. In some cases it was very hard to see on the videotape whether somebody is "only thinking" or actually looking at a representation for reference purposes.

We also found that in some cases a gesture was performed on a document, whereas in other cases it was made in the air. For example, in some cases subjects would first gesture in the air to explain some design idea, and only later draw the idea on paper. Subjects switched frequently between these two options. Since these actions were an intricate part of the communication process we thought they should also be included in the coding scheme.
4.5 Conclusions

The importance of the various action types differs between one task and another. Determining what actions are used for specific tasks can aid developers of design support in deciding their priorities in what actions to support and thus what technologies to offer. In this way we can study what actions are used to explain design ideas to other team members, or to the users. We can also study for what tasks designers choose actions that leave a permanent record, rather than ephemeral actions.

Because actions are not always performed on representations the coding scheme should include all actions performed, not just the actions performed on the representations.
5. The use of gestures for design and management activities in design meetings

5.1 Introduction

Due to the fact that products are becoming more complex, it is becoming harder to develop easy to use user interfaces. Instead of having individuals develop user interfaces, companies are advocating that teams should work on such complicated tasks. Teams commonly include people from different disciplines, with diverse backgrounds. Earlier research has shown that such design teams need support for communication (Bekker and Vermeeren, 1993). Good communication support is important because the design process is complex, and the decisions have to be clear to all members of the team. Communication is also important because, to understand one another, the team members from different disciplines have to develop a joint terminology.

Because communication is such a complicated process, more research is needed to understand how it should be supported. One way to guarantee that tasks are efficiently supported, is to ensure that the tools are appropriate for the task they must support, i.e. that there is a task-technology fit (Teasley et al., 1993). Technology influences what actions have to be undertaken to perform a certain task, e.g. when writing a document with pen and paper, one has to hold the pen and move it across the paper, whereas when writing a document with a text editor one has to type.

If we determine what actions are used to perform a task or sub-task (activities), we can infer what technology to offer for a specific task. In this way, we can adapt the technology we offer to the actions, and in turn the tasks that have to be performed with the technology. Based on our findings described in Chapter 4 we decided not just to study actions performed on representations, but all actions made. Since we were interested in what technology is needed for the support of design teams, we decided to examine the relationship between actions (e.g. drawing, gesturing, speaking, and writing) and activities (discussing design issues, managing the meeting) during the design process. In this way we wanted to determine whether it is possible to adjust design support to the task that it has to support.
We were especially interested in the activities for which the actions - such as drawing, gesturing, speaking, and writing - are used. Each type of action has its own characteristics that influence for what purposes it will be used. Examples of such characteristics are, the time and effort needed to conduct an action, whether it can be conducted simultaneously with other actions, whether it leaves a permanent record (such as drawing and writing) or is ephemeral (speaking and gesturing). Depending on the activity for which an action has to be used, some actions may be more appropriate than others. Clark and Brennan (1989) even go so far as to say that people communicate according to the principle of least collaborative effort: i.e. people who communicate try to minimise their collaborative effort to reach a common goal. That would mean that people choose the most appropriate action according to the principle of least collaborative effort.

We decided to focus on one of the actions, because it would be too time-consuming to study all types of actions. We wanted to examine whether any relationships could be found between actions and activities. If so, then the framework could later be used to study the other actions. Of the various actions that are used by design teams for communication, drawing and writing have been studied extensively (e.g., Scrivener et al., 1993, Baecker et al., 1993). How gestures contribute to the communication process, however, has received much less attention. The few studies that do report on the use of gestures offer some insight into the purposes for which gestures are used. Tang (1989, 1991), for instance, found that while 65% of designers’ actions included the making of lists and drawings, a full 35% of the actions were gestures. He described these gestures as serving to engage attention and to express ideas. Harrison and Minneman (1994) found hand gestures were used to describe the object under discussion, to suggest alternative forms, and to refer to locations. Gestures also clarified verbal utterances and illustrated the use of a product by a customer or user. In the work which has been undertaken, for example by Tang (1989, 1991) and Bly (1988) the behaviour of only one group and by Harrison and Minneman’s (1994) three groups of designers have been analysed. Furthermore, the researchers did not distinguish between different types of gestures (Bly coded only point gestures).

Gestures have a number of attributes that make them attractive for certain purposes. Gestures are evanescent and thus do not take up space after being made. Gestures have a low cognitive load, they take little time to prepare and deliver, they can be made simultaneously with speech, and
they can convey complex information in a very compact form. Gestures are especially important for design tasks because designers use gestures to convey how users would interact with the interface. They can also be used to convey other information about the design, such as spatial information about (parts of) the design, and relationships between parts of the design in a compact way. The assumption that designers would continuously use such a powerful means of communication fits in with the idea of least collaborative effort (Clark and Brennan, 1991).

In the present study we examined whether the actions versus activity framework is a useful procedure to determine how design support could be adjusted to the task that it has to support. Furthermore, we determined for what activities speech-related gestures are used by design teams. We only coded speech related gestures, because the coding of the activities were based on the content of the verbal utterances. We were interested in how such an easy to produce and powerful means of communicating would be used in design meetings.

We were also interested in the influence of tools that the groups have available on the purposes for which gestures were used. Therefore, we decided to compare basic tools: paper, pencil and a whiteboard with a technology driven tool: a shared text-editor, and a whiteboard. We offered half of the groups the first tool set, and the other half of the groups the second tool set.

5.2 Methods

To determine what actions are used to perform design and procedural (e.g., management of recorded information and meeting) tasks we analysed the data of 20 groups who worked on a design task early in the design process. The task was undertaken in a laboratory setting.

5.2.1 Experimental set-up

Data collection
We decided to use data already gathered by experimenters of the Cognitive Science and Machine Intelligence Laboratory at the University of Michigan in Ann Arbor (see also the considerations in the Subjects section). The data had already been transcribed and the design meeting activities coded to study the impact of using a shared text-editor on the collaboration within design teams (Storrøsten, 1993). For the present study
we coded the gestures and linked the design meeting activity and the gesture coding schemes together. In this way we could test our ideas on a larger data set than otherwise would have been possible.

**Subjects**
We considered using data of design teams in practice, however, it would have been impractical to compare the data gathered in real companies because in practice tasks, the team sizes and time spent on a design vary between groups. For the sake of comparability of design tasks and accessibility of subjects we decided to use MBA (Master of Business Administration) students as subjects. Subjects had experience with working in practice (on average 5 years) and were educated in working on similar tasks.

Twenty groups, each consisting of MBA students, participated in the experiment. All subjects were paid, and for some participants the experiment was also part of a class exercise. The MBA groups were selected according to the following two criteria:
- the participants in a group had to have previous working experience working together in that same group
- all participants had to be able to use Macintosh computers

**Design**
The groups in the supported condition used a group editor, ShrEdit (McGuffin, 1992), and they also had access to a whiteboard. The unsupported groups used a whiteboard, paper and pencil (see Figure 5.1). Each group was randomly assigned to either the supported, or the unsupported condition.

**Procedure**
The groups were given a total of three tasks. The first two tasks were warming-up tasks, so that the groups using the text editor could become used to working with the technology. The third task was the target design task. We chose a task that had been previously validated as being representative of what designers do in the field (Olson et al., 1992). The total session took three hours, the last one and a half hours of which was spent working on the target task. The subjects had to investigate the functionality, equipment necessary and working procedures of an Automated Post Office (see Appendix 3). Video and audio recordings were made of all sessions.
Figure 5.1
The laboratory setting in which the three people of the unsupported groups (panel a) and the supported groups (panel b) had to work on the task.

5.2.2 Coding the design meeting activities
The coding of the design meeting activities was performed by experimenters of the Cognitive Science and Machine Intelligence Laboratory at the University of Michigan in Ann Arbor for another purpose (Storrorsten, 1993). All verbal interaction among the participants of the design meeting was transcribed and time-stamped. The transcript was divided into clauses. Next, the data were coded using the design meeting activity scheme. They used an existing coding scheme that categorises different types of activities in design meetings (Olson et al., 1992). The scheme contains codes for group management (e.g., meeting and writing management), design rationale (e.g., design issues, alternatives and criteria) (Moran and Carroll, in press) and "other" activities that are not directly connected to the task (for more details see Appendix 4). To get an indication of how well the supported groups worked with the new technology a separate design meeting activity category (technology confusion) was included in the coding scheme.

Coding of the transcript consisted of segmenting the transcript into parts that consisted of a single type of design meeting activity, and determining
the type of design meeting activity for each of those segments. The coding scheme is exhaustive, i.e. it covers all verbal interaction, and the coding categories are mutually exclusive, i.e. each utterance can be coded by only one code.

The agreement between two coders that tested the coding scheme was 63%, using Cohen's $\kappa$ (Cohen, 1960). A more detailed description of the coding of the design meeting activities can be found in Olson et al. (1992).

Storrøsten (1993) includes "walkthrough" in the procedure activities based on empirical grounds. However, we decided to include "walkthrough" in the design activities instead of in the procedure activities, since this is also an activity during which the design is discussed, and not so much an activity during which management is discussed.

5.2.3 Coding gestures
In agreement with McNeill (1992), we chose to code only those gestures in which the group member used hands or arms, not just fingers. We examined the coding schemes of Ekman & Friesen (1969) and McNeill (1992) that have been used to describe face-to-face interactions, and used four categories that are simplifications of the more complex categories found in their schemes. We used this simplification both to improve the agreement between coders (see section 5.2.4 Agreement between coders on the gesture coding scheme) and to span the kinds of gestures we actually saw in the videotapes. We adapted their scheme by combining some of their categories, those we were not specifically interested in, into one category in our coding scheme (other). Our coding scheme distinguished between the following types of visual relationships between act (the movement or gesture) and significant (i.e. what it signifies):

- **Kinetic**, the movement executes all or part of an action performance (see for example Figure 5.2).
- **Spatial**, the movement indicates distance between people, objects or ideas (see Figure 5.3).
- **Point**, some part of the body usually the fingers or the hand, point to some person, to some part of the body, to an object or place (see Figure 5.4). Or, the referent may be a more abstract attitude, attribute, affect, direction, or location.
- **Other**, combination of rhythmic gestures that trace the flow of an idea or accent a particular phrase, or describe the rates of some activity, regulators, and all other gestures with hand(s) and / or arm(s), not categorizable in any of the above categories.
The use of gestures for design and management activities

We are mostly interested in the first three categories, that contain gestures that convey information about the content of the communication. The last category 'other' contains mostly gestures that convey the structure and importance (of parts) of the communication.

Figure 5.2
A kinetic gesture illustrating the interaction between the user and the interface of the product. ("When you pay for it, how do you pay for it?")

Figure 5.3
A spatial gesture indicating the size of an object ("Some guy, or some person, comes in with a huge stack of letters").
Figure 5.4
A point gesture referring to information on the whiteboard ("we can correspond the equipment needed to the numbers of the functions").

5.2.4 Agreement between coders on the gesture coding scheme
Two coders developed and discussed the rules for coding the four types of gestures, until they felt that most misunderstandings about how to apply the rules were resolved. On completion of the development of the coding rules (see Appendix 5 for the final rules), both coders coded one design meeting to determine their level of agreement. Afterwards, they discussed why some gestures had been coded inconsistently, to understand what had caused their disagreement. In this way rules for gesture coding were developed with a consistency that would allow use by other researchers (after some training).

For each clause the coders determined whether gestures occurred or not, when a gesture occurred, they then decided on its particular code. One or more gestures could occur during each clause. The agreement was determined by comparing the coding of the two coders per clause. The overall agreement, i.e. the agreement on the complete coding scheme, and the category-by-category agreement, i.e. the agreement on each of the categories, was determined.
5.2.4.1 Overall agreement between coders
The overall agreement between coders was determined using Cohen's kappa (Cohen, 1960) \( \hat{\kappa} = \frac{p_o - p_c}{1 - p_c} \), where \( p_o \) is the proportion of ratings in which the two coders agree, and \( p_c \) is the proportion of ratings for which agreement is expected by chance.

We determined the level of overall agreement where both coders agreed that a gesture had occurred. The two coders agreed in 849 of the 1063 codes (\( p_o = 0.80 \)). After compensating for the cases for which agreement is expected by chance (\( p_c = 0.34 \)) they agreed to a level of 72% (\( \hat{\kappa} = 0.72 \)). More detailed information about the agreement between the two coders is given in Appendix 6.

5.2.4.2 Category-by-category agreement
We also determined category-by-category agreement (Fleiss, 1971), to gain insight into the agreement of the coders on each category. The formula for category-by-category agreement is \( \hat{\kappa}_i = \frac{\bar{p}_j - p_i}{1 - p_i} \), where \( p_i \) is the proportion of ratings that were coded into a particular category, and \( \bar{p}_j \) is the conditional probability that if one coder assigns a gesture to category \( j \), a second coder will also. The agreement per category was highest for the coding of kinetic gestures (\( \hat{\kappa} = 0.81 \)) and lowest for the coding of point gestures (\( \hat{\kappa} = 0.60 \)). For spatial and other gestures we found \( \hat{\kappa} = 0.67 \) and \( \hat{\kappa} = 0.66 \), respectively.

5.2.5 Analysis
For each clause in the transcript the type of design meeting activity and the types of gestures were determined independently. To determine what types of gestures were used for what types of activities we determined how much time was spent, and how many gestures were made during each activity. Since groups varied in the time they spent talking, and we assumed that the number of gestures was related proportionally to the time spent talking (the more time spent talking, the higher the number of gestures), we based our analysis on the number of gestures per second instead of simply the number of gestures.

We used this data to test the following hypotheses (for which we set the probability of falsely rejecting the null hypothesis equal to 0.05):
Hypothesis A: The use of gestures for design meeting activities
We wanted to examine whether groups used more gestures for design than for procedure activities, to determine the design of support could be adjusted to the task that is to be supported (task-technology fit). Because a 3D-object was being designed, and team members had to convey information about the product and the user actions to each other, it was likely that gestures would be used more often as a support for verbal information during the explanations of design ideas than during management activities. Therefore, we predicted that groups would use more gestures during design activities than during procedure activities (hypothesis A1). Since kinetic gestures were expected to be especially important for the design activities to explain both the gestures made by users interacting with the product and the way the product would work, we also tested this hypothesis (A2) for kinetic gestures, separately. Furthermore, because we expected that point gestures would also be important while discussing design ideas, for references to objects, persons and places, we also tested this hypothesis (A3) for point gestures, separately.

Hypothesis B: The influence of the available tools on the actions used
We wanted to study whether the actions that are chosen for a certain task are influenced by the available tools. This would give us insight into whether a task-technology fit might change if another set of tools would be offered. Groups using paper, pencil, and a whiteboard (unsupported groups) would use more gestures than groups using the shared text editor (supported groups), and a whiteboard (hypothesis B1). One explanation for the difference could be that groups using the text editor are more inclined to keep their hands on or near the key-board, and therefore are less inclined to gesture. We expected that the difference would be found, both for kinetic (hypothesis B2) and for point gestures (hypothesis B3), because these gestures are important for descriptions of design ideas.

To compare the frequency of gestures we used the average number of gestures executed per second. We defined the average number of gestures per second over the whole meeting as the total number of gestures divided by the total time spent talking. Since the time spent in each of the design meeting activities varied, the average number of gestures per second over the whole meeting, was not equal to the sum of the averages of the number of gestures per second over all design meeting activities divided by the number of design meeting activities. We defined the average number of gestures for a specific category of activities (e.g., design or procedure
activities) as the sum of gestures in this category of activities, divided by the total time spend talking during the category of activities.

5.3 Results

We analysed the behaviour of the design groups that came up with a design for an Automatic Post Office. The videotapes were coded using two coding schemes: the design meeting activity scheme, and the gesture coding scheme. In this section we will give a summary of the data related to time, on number and frequency of gestures and then we will test the hypotheses that we stated in the analysis section.

5.3.1 Time spent talking during meeting
Figure 5.5 shows the time that each group spent talking during the meeting. The amount of time spent talking varies considerably between groups. The average time spent talking was 69 minutes (range is 35 - 81 minutes). The supported and the unsupported groups spent an average time talking of 63 and 67 minutes, respectively.

![Bar chart showing time spent talking in minutes for each group. Supported groups are on the left, unsupported on the right.

Figure 5.5
The time spent talking (in minutes) for each of the groups. Groups 1 to 10 used the shared text editor and a whiteboard and groups 11 to 20 used paper, pencil, and a whiteboard.
5.3.2 Number and frequency of gestures
For each group we coded how many gestures (point, spatial, kinetic and other gestures) were used during the meeting. Figure 5.6 gives an overview of the number of gestures executed for each of the groups: groups 1 to 10 used the shared text editor and groups 11 to 20 used paper and pencil.

On average the groups used 651 gestures, with an average of 89 kinetic, 41 spatial, 138 point, and 383 other gestures. On average the supported groups used 498 gestures (71 kinetic, 103 point, 37 spatial and 287 other gestures), and the unsupported groups 805 gestures (108 kinetic, 173 point, 45 spatial and 480 other gestures).

Since we only coded speech related gestures, and the time spent talking varied considerably between groups we also calculated how many gestures (kinetic, spatial, point and other gestures) per second talking each group made (see Figure 5.7).
Figure 5.6
Number of gestures (kinetic, spatial, point and other gestures) used during meeting. Groups 1 to 10 used the shared text editor and a whiteboard, and groups 11 to 20 used paper, pencil and a whiteboard. Note that the lines in Figure 5.6 and Figure 5.7 have no meaning apart from grouping symbols of the same set.

Figure 5.7
The number of kinetic, spatial, point and other gestures per second for each of the twenty groups. Groups 1 to 10 used the shared text editor and a whiteboard, and groups 11 - 20 used paper, pencil and a whiteboard.
5.3.3 Time spent talking per design meeting activity
Figures 5.8 shows how much time is spent talking in each of the design
meeting activities by the supported, and the unsupported groups,
respectively. It shows that the unsupported groups (grey boxes) spent the
same or more time in all design meeting activities than the supported
groups (white boxes), except in meeting management, technology
management and technology confusion activities.

5.3.4 Number of gestures per second per design meeting activity
Figure 5.7 gave an overview of how frequently gestures were used per
group over the entire meeting. To gain an insight into how the frequency
of gestures varied over the various activities, we also calculated the
frequency of gestures for each of the design meeting activities. Figure 5.9
indicates that unsupported groups (grey boxes) use the same or more
gestures per second than supported groups (white boxes) during all design
meeting activities, except during technology management and technology
confusion.

5.3.5 Number of gestures for design versus procedure activities
To determine whether the frequency of gestures is influenced by the type of
activity, we tested whether the number of gestures per second of the
groups differed between design and procedural activities. Figures 5.10 to
5.14 show the numbers of gestures per second for total, kinetic, point,
spatial and other gestures, respectively. The figures show that the groups
used more gestures per second for design than for procedure activities for
all types of gestures, except point gestures. The unsupported groups used
more point gestures per second for procedure than for design activities
(see Figure 5.12).
Figure 5.8
Time (range, quartiles and median) spent in design meeting activities in seconds by unsupported (grey boxes) and supported groups (white boxes). The vertical dashed lines indicate which design meeting activities fall into the design, the procedure and the other design meeting activities categories.

Figure 5.9
The number of gestures per second that occurred in each of the design meeting activities (the maximum, quartiles, the median and the minimum) for the unsupported (grey boxes) and the supported groups (white boxes). The vertical dashed lines indicate which design meeting activities fall into the design, the procedure and the other activities categories.
Hypothesis A1: Groups use more gestures during design than during procedure activities
The groups used significantly more gestures per second for design than for procedure activities (paired t-test; t_{19} = 8.3, p < 0.001). Figure 5.10 shows that this is the case for both supported and unsupported groups.

Hypothesis A2: Groups use more kinetic gestures during design than during procedure activities
A paired t-test revealed a significant difference between the number of kinetic gestures per second for design and procedure activities (t_{19} = 8.2, p < 0.001). Figure 5.11 shows that this is the case both for the supported and the unsupported groups.

Hypothesis A3: Groups use more point gestures during design than during procedure activities
No significant difference was found between the number of point gestures per second during design and procedure activities (t_{19} = 0.007, p = 0.58). Figure 5.12 shows that most unsupported groups used more point gestures during procedure than design activities, and most supported groups used more point gestures during design activities than during procedure activities. Paired t-tests showed that supported groups used significantly more point gestures during design activities (t_{9} = 2.06, p = 0.035), and unsupported groups used more gestures in procedure than design activities (t_{9} = -2.33, p = 0.022).

Figure 5.10
The number of gestures per second during design and procedure activities for all 20 groups. Groups 1 to 10 used the shared text editor and a whiteboard, and groups 11 to 20 used paper, pencil and a whiteboard. Note that the lines in Figure 5.10 to Figure 5.14 have no meaning apart from grouping symbols of the same set.
Figure 5.11
The number of kinetic gestures per second during design and procedure activities for all 20 groups. Groups 1 to 10 used the shared text editor and a whiteboard, and groups 11 to 20 used paper, pencil and a whiteboard.

Figure 5.12
The number of point gestures per second during design and procedure activities for all 20 groups. Groups 1 to 10 used the shared text editor and a whiteboard, and groups 11 to 20 used paper, pencil and a whiteboard.

Figure 5.13
The number of spatial gestures per second during design and procedure activities for all 20 groups. Groups 1 to 10 used the shared text editor and a whiteboard, and groups 11 to 20 used paper, pencil and a whiteboard.
Number of other gestures per second for design and procedure

![Graph showing number of other gestures per second for supported and unsupported groups.](image)

**Figure 5.14**
The number of *other* gestures per second during design and procedure activities for all 20 groups. Groups 1 to 10 used the shared text editor and a whiteboard, and groups 11 to 20 used paper, pencil and a whiteboard.

5.3.6 Number of gestures for supported and unsupported groups
To determine whether the tools available to the groups affected their behaviour, we compared the number of gestures per second used by the unsupported and supported groups.

*Hypothesis B1: Unsupported groups use more gestures than supported groups.*
The unsupported groups used significantly more gestures per second (t-test: $t_{18} = 3.06$, $p = 0.003$), than the supported groups (see Figure 5.15). Figure 5.9 shows that this difference is not only due to the fact that the numbers of gestures per second in design activities are higher, but that unsupported groups use more gestures per second than supported groups, during almost all design meeting activities. Paired t-tests show that unsupported groups use more gestures per second than supported groups during procedure activities ($t_{18} = 2.40$, $p = 0.014$), but not during design activities ($t_{18} = 0.87$, $p = 0.20$).

*Hypothesis B2: Unsupported groups use more kinetic gestures than supported groups.*
No significant difference ($t_{18} = 1.65$, $p = 0.058$) was found between the number of kinetic gestures per second by supported and unsupported groups (see Figure 5.15).
Hypothesis B3: Unsupported groups use more point gestures than supported groups.
The unsupported groups used significantly more point gestures per second ($t_{18} = 2.84, p = 0.005$), than the supported groups (see Figure 5.15). Paired t-tests show that the unsupported groups used significantly more point gestures per second than the supported groups during procedure activities ($t_{18} = 3.65, p = 0.0009$), but not during design activities ($t_{18} = 0.93, p = 0.18$).

![Graph showing number of gestures per second by type of gestures: kinetic, spatial, point, and other.](image)

**Figure 5.15**
Number of kinetic, spatial, point and other gestures (averages, standard errors and 1.96 * standard errors) for supported (white boxes) and unsupported groups (grey boxes).

### 5.4 Discussion

Twenty groups worked on a task early in the interface design process to determine for what purposes gestures are used. To determine how the available tools would effect the group's behaviour, we offered ten groups basic tools, such as paper, pencil and a whiteboard (unsupported groups), and the other ten groups a shared text editor and a whiteboard (supported groups).
5.4.1 The use of gestures
We examined whether gestures were used more often for design than for procedure activities. Our study showed that both the supported and the unsupported groups used comparatively more gestures per unit of time spent on an activity, during design than during procedure activities. As we predicted, (both supported and unsupported) groups also used more kinetic gestures per second during design activities. Kinetic gestures are categorised as containing all sorts of information, ranging from information about the size of the product to the sequence of actions performed on the product. Having to convey this information through another medium, such as speech, would take much more time and effort. Our results also show that the supported groups used more point gestures per second for design than for procedure activities, while the opposite holds for the unsupported groups; they use more point gestures during procedure activities.

Each type of gesture was used for different purposes. For example, point gestures were used to direct attention to a piece of information during design activities, whereas they were used to appoint a task to somebody during procedure activities.

5.4.2 The effect of the available tools on the use of gestures
We compared the use of gestures by groups using paper, pencil, and a whiteboard, with the use of gestures by groups using the shared text editor, and a whiteboard. We found that groups which used paper, pencil and whiteboard used more gestures relative to the time spend talking than the groups that used the shared text editor. They used more point gestures per second than the groups using the shared text editor. No significant difference was found in the number of kinetic gestures per second by the supported and the unsupported groups. The difference in the use of gestures by the supported and the unsupported groups was largely caused by the difference in the use of point gestures by the groups: unsupported groups used more point gestures per second than supported groups.

A possible explanation for the differences in behaviour between the unsupported and the supported groups might be found by comparing the use of the whiteboard with the use of the shared text editor. Some evidence was found in studying the videotapes. Most unsupported groups used the whiteboard (functioning as a workspace accessible for everybody) for the major part of the session. They did not start using paper and pencil until they began working on the final document. The whiteboard was not suitable for documentation of the design and therefore groups switched to
using paper and pencil. However, most supported groups did not use the whiteboard, they only used the shared text editor. Further supporting evidence was found in Storrøsten (1993). She compared the time spent discussing the design by the supported and unsupported groups and found a significance difference.

Below is a list of the practical differences between the use of a whiteboard and the shared text editor:
1) A whiteboard has limited space to write things down.
2) A whiteboard does not have a copy and paste possibility.
3) A whiteboard leaves limited possibility for parallel work (only one person can write down ideas at a time), whereas with the shared text editor parallel work is possible.
4) It is easier to show links between information (e.g., links between functions and necessary equipment) on a whiteboard.
5) It is easier to gesticulate to information on a whiteboard than on the shared text editor. The participants using the shared text editor cannot gesticulate to information in the shared window, they can only direct attention to it using speech or advising others to track their cursor.

More point gestures were used by the groups which used paper and pencil and a whiteboard: they indicated links between the different topics more often (see item 4), and they had to do more management activities (e.g., who should record what part of the information) when they started writing the document (see item 2). They also used more point gestures to direct attention to information (see item 5).

We found that the supported and the unsupported groups used different strategies to complete the task. It is evident on the videotapes in the way they approach the task. Most groups using a whiteboard did the brainstorming part of the task together, whereas most groups using the shared text editor performed the brainstorming part of the task separately, and combined everybody’s ideas afterwards, often without an extensive discussion to select the most feasible ideas (see item 3). Further support for this finding can be found in (Storrøsten, 1993). She found a significant difference between the supported and unsupported groups in the time they spent discussing the design.

In the present study, the groups using the shared text editor could direct attention to a particular part of the document using speech, or the cursor. However, determining the position of somebody else’s cursor is not as easy
as determining to what somebody else's gesture is referring. Subjects often asked other participants at what part of the document they were working.

They also used an interface tracking function to determine where the others were in the document. However, having to use this function was rather disruptive during an exchange as, instead of gesticulating and automatically receiving everybody's attention, participants had to wait until the whole group had found the area of interest through the cursor.

5.4.3 Actions versus activities framework
We found that gestures are used for activities in different ways. For example, gestures are used more often for design than for procedure activities. These results show that the framework can be used to determine how to adjust a design to the task that has to be supported. The results can help designers in prioritising design considerations. For example, if design considerations for support of different actions lead to conflicting design decisions, the framework can be used to assist in finding an appropriate solution.

In future research the framework can be used to study some of the other problems that we found in Chapters 2 and 3, such as how designers communicate with team members of a different discipline, and with users. To better understand the complex process of communication we will have to study more than one type of action in the future. For example, to determine in what cases they use actions, such as writing and drawing to capture the design discussion, and in which cases they choose ephemeral actions, such as gestures. In this way we can determine how support can be adjusted to other tasks that need improved support.

5.4.4 General discussion
Our study has covered a small, but so far relatively unstudied, part of the research needed to understand communication in design groups. The present study shows that the behaviour between groups is diverse; some groups use many gestures during a meeting, whereas others use few (see Figure 5.6).

Apart from available tools, other important factors which affect the choice of actions to perform design meeting activities are team size and the task at hand. For example, as team size increases a question such as "Could you write that down?" becomes harder to understand. We also believe that behaviour is affected by the phase of the design process the task represents. For example, in our study we used a task early in the design
The use of gestures for design and management activities

process and consequently the amount of time spent drawing was limited. In a later phase of such a design project more drawings would have to be made. Another factor that can affect the use of actions is the background of team members. People with graphic or industrial design backgrounds may be more inclined, and able, to draw than people with computer science or psychology backgrounds.

5.5 Conclusion

We studied the use of gestures by design teams and found that all types of gestures (kinetic, point, spatial and other gestures) are used both for design and for procedure activities. Some types of gestures, such as kinetic gestures, are used more for design activities than procedure activities. Other types of gestures, such as point gestures by unsupported groups, are used more for procedure activities. This means that each type of gesture is used for various purposes, and how it is used is influenced by the tools which are available.

The fact that the use of gestures is influenced by the available tools is most clearly illustrated by the use of point gestures in this study. The supported groups used more point gestures for design than for procedure activities, whereas the unsupported groups used more point gestures for procedure activities. This happened because the unsupported groups had to spend more time on rewriting and managing the information (on the whiteboard) in comparison to the supported groups. The groups using the shared text editor could work more in parallel, and consequently they used fewer gestures relative to the time they spent talking than the unsupported groups. This difference was largely caused by the fact that they had a copy and paste facility available to them, and thus had less rewriting and managing of information to undertake than the unsupported groups.

The intention of developing new tools is generally to improve the efficiency of a task. The fact that this may change the behaviour of a group does not have to be a problem. However, there is always the possibility that the introduction of new tools inadvertently causes another part of a person’s work to deteriorate. Therefore, it is important to understand how behaviour changes. In the present study, we saw that groups with the text editor used fewer gestures than the groups using paper and pencil. Gestures and other visual conduct are used to encourage others to participate in the conversation (Heath and Luff, 1992) and to focus attention (Bly, 1988). As a consequence, it may be possible that the
supported group members were less focused on the design tasks or that they needed relatively more explanations of the design ideas being proposed by other team members.

Since little is known on how the quality of the final design is affected by gestures, more research is needed to determine in what way gestures contribute to communication. This study shows that gestures are used both for design and procedure activities. It indicates that different types of gestures are used for different types of activities, and that this is influenced by the tools that are offered. Assuming for the time being that gestures do contribute to communication, the study also indicates what gestures have to be supported for design and procedure activities.

In this chapter we showed that the actions versus activity framework can be used to tailor design support to the task that has to be supported. Furthermore, we described for what activities gestures were used and how their use was influenced by the available tools. In the next chapter we will translate these findings into recommendations on how to support gestures.
6. The purposes of speech-related gestures used in design meetings, and how gestures can be supported in groupware tools

6.1 Introduction

Designing user interfaces is a task that is performed more and more by groups, rather than by individual designers (Bekker and Vermeeren, 1992, 1993). Recently, the trend has been to form design groups on the basis of expertise, rather than on the location of team members. But even without having to face the problems that stem from working in different locations, there are recognised difficulties with the way groups naturally work (e.g., systematically weighing all the advantages and disadvantages of options, that have been mentioned by the group members, so that the proper decision can be made) that suggest that some kinds of groupware technologies might be helpful in supporting this activity.

The aim of this chapter is to come up with a list of recommendations for support of gestures in groupware products. Firstly, we discuss the groupware products that are on the market today, and how groupware products fail to support gestures. Secondly, we give an overview of literature on gestures relevant for our list of recommendations. Following the literature we describe our study on the use of gestures by co-located design teams (i.e. all team members are located in the same room) and finally, we present a list of recommendations for support of gestures in co-located and distributed settings (i.e. team members are located at various locations).

6.1.1 Groupware products
There are a number of groupware products on the market today targeted to support both face-to-face and remotely located groups. For asynchronous coordination, there are shared file servers with README files and Lotus Notes files with attached discussion databases. For synchronous work, there are applications that allow screen and window sharing of any application (e.g., Shared-X, Timbuktu), some innately sharable text/drawing editors (e.g., Aspects, LiveWorks, Smart 2000), as well as shared "notebooks" into which group members can paste bit-mapped pictures of documents from other applications and annotate or

mark them. Furthermore, there is a variety of products that include video connections to support real-time groups who are remotely located. These range from expensive video conferencing systems based on high quality analogue video to desktop systems based on ISDN connections (e.g., AT&T's Vistium, Intel's ProShare). Even though many studies have analysed the uses of video by remote groups, there continues to be considerable debate about what video connectivity actually adds to distributed work, apart from the improved satisfaction of the participants (e.g., Olson et al., 1995).

These groupware technologies vary both in their base functionality and in their support for the actions performed by a group. Base functionalities include such aspects as how many participants can enter and edit the base document simultaneously and who is locked out when others are working on the document. Actions encompass gestural actions that happen naturally in groups that meet face-to-face with traditional technologies, such as whiteboards and paper and pencil.

In particular, few of today's groupware applications, except high quality video connections, support the full range of gestures such as indicating with the hands the size or location of something or animating an action so others see quickly what is meant without long discourse. Some groupware applications provide a "telepointer" intended to support group members' pointing to things on their screens (e.g., Aspect, ProShare, Point to Point) and some prototype groupware applications (e.g., Clearboard, Ishii et al., 1993) blend desktop, hand gestures, and even eye gaze in a setting for "natural" remote communication.

6.1.2 Relevant literature on use of gestures
We now discuss literature on support for and the use of gestures that are relevant for recommendations for support of gestures. Studies on video-mediated communication have shown that supporting gestures effectively is not as easy as it seems. For example, the analysis of affordances (i.e. properties of the environment that offer actions to the users) of media spaces by Gaver (1992) gives an interesting overview of the properties of video technology, and how the properties affect support for gestures. He explains that because video offers a restricted field of view (narrower than with a motionless head and eyes), peripheral vision (used to be aware of gestures) and the possibility for perceptual exploration are limited. Furthermore, because it is unpredictable what each participant can see, and participants do not have a shared space, it is hard to adjust gestures to the "shared environment". In a study which examines the benefits of
offering more than one head-and-shoulders view on screen, Gaver et al (1993) found that multiple views (through the use of multiple cameras) offer some benefits, but still do not solve the problem of having sufficient information about, and access to, the shared environment. Another study on video mediated communication has shown that video technology distorts the size, the shape and the pace of gestures, making interpretation of gestures difficult (Heath and Luff, 1991; Heath and Luff, 1993). These studies show that designing appropriate support for remote groups is difficult, because the importance of many subtle communication issues has to be recognised and solutions for their support have to be found.

So, what speech-related gestures do people use when they design face-to-face with traditional tools? Some studies have looked at the role of gestures in group design tasks; Tang and Leifer (1988) and Tang (1989) found in their studies that 65% of the hand actions included the making of lists and drawing and 35% of the hand actions were gestures. They described these gestures as serving to engage attention and to express ideas. Harrison and Minneman (1994) found hand gestures that described the object under discussion, suggested an alternative form, and referred to locations. Gestures also clarified verbal utterances and illustrated the use of a product by a customer or user. These groupware researchers have provided insights into some of the purposes for which gestures are used by designers.

Research from other fields has shown that gestures also serve to indicate who is to speak next (Duncan, 1972), and to help others understand the structure of what is being said (e.g., while pointing to one finger and then another or one hand and then the other hand, saying "On the one hand there is one idea, and on the other hand another idea"; cf. McNeill, 1992).

6.1.3 Recommendations for support of gestures
What we are concerned with in this chapter are descriptions of how communication is conducted when it is possible to use both speech and gesture. When groupware does not support both faculties people automatically adapt - but at a cost. For example, describing, instead of acting out, locations or animations is possible, but it takes more thought and words. Also, by studying what people do naturally, there is the possibility of enhancing communication in ways unattainable with face-to-face contact, i.e. through technology which goes beyond what is possible with face-to-face interaction. For example, being able to see somebody's face and the object they are looking at, blended together, without having
to change the direction of a glance, as is possible in Clearboard (Ishii et al., 1993).

Within this chapter we examine what kinds of gestures are actually used by groups working in face-to-face settings on a standard design task. Our goal is to draw together two types of information to suggest what the issues are important in thinking about how groupware systems should support gesturing in design: (a) the prior literature on gestures, as briefly described above; and (b) observations of our design material described in this chapter.

Firstly, we describe our study on the use of gestures by design teams. We use the insights gained through this study to show that the types of gestures are used for different purposes (i.e. parts of the task). We also show that each type of gesture has its own set of characteristics important for interpretation, and thus that each type of gesture can be supported in its own way. Based on information in the literature on gestures, and the observations described in this chapter, we discuss what recommendations for gesture support have to be considered for a supported face-to-face and a distributed setting. The results of this study are thought to be especially relevant for developers of groupware tools. They can be used to help developers decide what gestures to support and how they should be supported.

6.2 Methods

We studied the use of gestures by design teams in face-to-face meetings. We asked twenty design groups, each consisting of three persons, to come up with a list of functions for an automatic post office. During the task ten groups used paper, pencil and a whiteboard, and the other ten used a shared text editor. Each team had ninety minutes to make the list, and write a short report containing the design ideas. The data that were used are the same as the data used for the study described in Chapter 5. For more details about the method, see Chapter 5.

We examined for what purposes the types of gestures were used. By comparing several instances (from the video clips) of similar uses of gestures, we determined what characteristics of the gestures were important for conveying the intended information. The method used to determine what information was conveyed through the gestures was
inspired by "interaction analysis" as described by Jordan and Henderson (1992).

6.3 The use of gestures for design meeting activities

We studied how gestures were used by design teams in a task early in the design process. The goal was to catalogue the types of gestures which occurred during three different types of design meeting activity:

(1) design activities, e.g. when design ideas are discussed,
(2) procedure activities, e.g. when what information has to be written down is discussed, and
(3) other activities.

Figure 6.1 shows that kinetic, spatial and other gestures are used most frequently for design activities, point gestures are used roughly equally frequent for design and procedure activities.

![Diagram showing number of gestures per minute by type of activity.](image)

**Figure 6.1**
The average number of gestures (kinetic, spatial, point and other) per minute over 20 groups, which were used for design, procedure and other design meeting activities. Note that the lines in this figure have no meaning apart from grouping symbols of the same set.

Gesturing occurred throughout the design meetings. Gesturing is an integral part of face-to-face design meetings. The number of gestures used by the groups varied from 4 to 14 gestures per minute, with an average of 9 gestures per minute. Moreover, all four categories of gesturing in our coding scheme occurred frequently (on average 1 kinetic, 1 spatial, 2 point
and 5 other gestures per minute). It is interesting to see that such a large number of gestures are used to convey information about the structure and importance of the conversation (other gestures).

6.4 The uses of gestures by design teams

Table 6.1 shows the kinds of gestures and how they were used for various purposes in the design meetings. Both single and sequences of gestures were used throughout the meetings. Firstly, we describe the uses of single gestures, and then we describe the purposes for which a series of gestures were used. Subsequently we illustrate our findings with figures based on the videotapes of the groups. The underlined parts of the transcripts coincided with the gestures made. The persons speaking and gesturing are coloured grey in the figures.

6.4.1 The use of singular gestures

Kinetic gestures
Table 6.1 shows that kinetic gestures were used to show different types of actions: actions of the users interacting with the product, the actions of moving information in documents and the actions of going through the design process. Kinetic gestures were mainly used to mimic how users would interact with the product. Figure 5.2 shows an example of a kinetic gesture that was used to describe the interaction between the user and the product. The underlined parts of the transcripts were uttered synchronously with the gesture.

During management activities, kinetic gestures were sometimes used to describe the actual process of the design. In such cases, a circular motion was used to describe the ongoing process. In other cases, kinetic gestures were used to describe the process of managing information. For example, when a team member told another team member to "Move that there", a kinetic gesture was used to visualise the intended move action.

Spatial gestures
Spatial gestures were mainly used to show sizes of objects, people, or distances between objects and people (see Figure 5.3). They were used when both design, and when management issues were discussed. In some cases one hand was used to make the gesture, whereas in other cases two hands were used. Spatial gestures often referred to (a part of) a document or the whiteboard. In other cases they referred to virtual information (see Figure 5.3). Other possible uses of spatial gestures, that we did not see in our data, are conveying more abstract qualities like similarity or other
meanings that have a distance-based metaphor (McNeill, 1992). Apparently, because designing interactive systems is a relatively concrete task, we only saw them used for the narrow purpose of specifying concrete characteristics of the design objects.

Table 6.1
An overview of the purposes for which each type of gesture was used, (K = kinetic, S = spatial, P = point, and O = other) X stands for used frequently.

<table>
<thead>
<tr>
<th>Purpose of gesture</th>
<th>Type of gesture</th>
<th>K</th>
<th>S</th>
<th>P</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Showing distances, sizes and shapes</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enacting the interaction between user and product</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referring to objects, persons or places</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listing items related to the design</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrasting two or more ideas, persons or objects</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Procedure /Management</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Managing of information, e.g. in documents, or on whiteboards</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managing actions, e.g. who does what?</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Discussing the design process, e.g. how many iterations to make</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Listing items in order to manage information</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrasting two or more ways to approach the task</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Referring to objects, persons or places</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Overall (*)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-taking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Indicating the structure of the verbal utterances</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Emphasising or focusing attention (other than turn-taking)</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) some utterances were made for multiple purposes, e.g. an utterance used to focus attention on some piece of information, was simultaneously used to discuss a design idea. Utterances made for an overall purpose also functioned a design, or a procedure purpose.
Point gestures

Point gestures were often used to refer to objects, persons, places or ideas. These gestures were used when design ideas were discussed, and also when the team discussed meeting management issues. Point gestures to objects often referred to (parts of) documents (see Figure 6.2), parts of the whiteboard (see Figure 5.4) or information on the computer screen. In some cases the gestures referred to very specific parts of a document, e.g. a word or sentence, whereas in other cases they referred to a more vague piece of information, e.g. some concept described in a document or an area on the whiteboard.

![Figure 6.2](image)

A point gesture indicating on the paper what the speaker is referring to ("This is the screen, this is where you input data").

Point gestures were also used to refer to persons or objects not present in the room. For example, people talked about a building somewhere else in the city, or a person working in another room (see Figure 6.3).

Other gestures

Other gestures were most frequently used to emphasise some part of a sentence. They were also used to indicate that a participant wanted to have the next turn in speaking and to indicate the structure of the verbal utterance. Other gestures were usually rapid and biphasic (two movement components).
Figure 6.3
A point gesture which refers to an object that is not present in the room ("Like for vending machines, down the hall").

6.4.2 Purposes of sequences of gestures
In some cases, gestures were used in series. In a series of gestures the hand(s) either moved back to the rest position for a few seconds, or the consecutive gesture was made immediately. Below we list a number of special purposes for which a series of gestures were used by the design teams.

- Walkthrough sequence
  Sequences of kinetic gestures were often used to describe the interaction between the user and a designed product (see Figure 6.4).

- List sequence
  Verbally listing (e.g., "So, what it is, what it's going to do, where it is.") while the group member indicates a numerical sequence on his/her fingers or one hand and the other. This is a sequence of pointing gestures (see Figure 6.5).

- Contrast sequence
  To illustrate contrasting ideas, often the point of contrast was signalled by the user pointing in one, and then in another direction (see Figure 6.6).
• **Emphasis sequence**
  The use of "other" gestures to indicate emphasis was often used in sequences of gestures. The gestures were sometimes used to indicate the structure of the sentences being uttered.

![Figure 6.4](image)

**Figure 6.4**
A series of kinetic gestures illustrating the interaction between the user and the interface of the product. Panel (a) shows a user action ("You have to key in on the screen that you want to weigh something"), panel (b) shifts to an action of the product ("Like the door could open up"), panel (c) again shows a user action ("You could put it on the tray"), and panel (d) shows another action of the product (and then it closes).
The purposes of speech-related gestures used in design meetings

Figure 6.5
Panel (a), (b) and (c) show how point gestures are used to walk through a list. (a) "So what it is.\text{,}" (b) "what it's going to do\text{,}" and (c) "where it is.\text{.}

Figure 6.6
Panel (a) and (b) illustrate how point gestures are used to show the contrast between two ideas; (a) "you could set up an account\text{,}" and (b) "or have it eat your money\text{.}".

6.5 Conclusions based on observations

We found that gestures were used throughout the meetings. They were used for all three types of design meeting activities (design, procedure and other activities). While kinetic, spatial and other gestures were used most
frequently for design activities, point gestures were used equally frequently for design and procedure activities.

Each type of gesture conveyed information in a slightly different way, e.g. the phase of the gesture that was most important, 2D versus 3D information, and needing one or two hands. The gestures referred to various sorts of information; in representations, to persons and objects or to virtual information that was not physically present.

6.6 Recommendations

Given this set of observations and those of others (described in the introduction, e.g., McNeill, 1992; Tang, 1989, Harrison and Minneman, 1994; Gaver et al., 1993; Gaver, 1992; Heath and Luff, 1992; Heath and Luff, 1993), we now describe recommendations for support of the four types of gestures by design teams. We are especially concerned with the following two cases:
1) when the group is face-to-face but might be using a group editor, like ShrEdit (McGuffin et al., 1992), where not all views of the shared object are the same.
2) in distributed settings, where not only is the shared object in a different location and perhaps a different page is presented on the screen (i.e. each participant determines what part of a document they see), but the participants may or may not be able to see each others hands and bodies (Olson, et al., 1995).

There are three sets of recommendations. The first set is based on the literature on gestures, and it applies to group design work in general and focuses on how gestures contribute to conversations in general. The second set is based on the observations described in this paper, and it applies specifically to the actual production of the gesture by the speaker and how it is captured. The last set is based on the literature and it applies to the visibility of the shared workspace for both the speaker and the receiver. For clarity, we have provided summary tables (Tables 6.2a, 6.2b, and 6.2c), which list the recommendations and refer to the types of gestures and the settings in which they occur. Each section is followed by textual description. User interface designers can use the recommendations as a checklist of things to consider when gestures are to be supported. The checklist indicates which recommendations to consider for face-to-face and distributed settings. The checklist can also be used combined with the action versus activity framework described in Chapter 5. In that case one
should first determines what gestures are important for a certain task using the action versus activity framework. Then one uses the checklist to determine what recommendations to consider when designing support for the selected types of gestures.

6.6.1 General recommendations

Table 6.2a

<table>
<thead>
<tr>
<th>SF</th>
<th>D</th>
<th></th>
<th>K</th>
<th>S</th>
<th>P</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A General recommendations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>1) Maintain synchrony with speech</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X 2) Facilitate the planning of gesture components simultaneously with planning of speech (and ease of production)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X 3) Offer an overview of available space (which can be seen by receiver) for gesturing and the information (re)presented in this space</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X 4) Facilitate switching between actions (e.g. between gesturing and drawing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X 5) Provide the possibility to make sequences and simultaneous gestures, and gestures using two hands (or substitutes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X 6) Allow people freedom to move around while gesturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) **Maintain synchrony with speech.**

   It is very important to maintain the synchrony between gestures and speech, to avoid confusion about the meaning of gestures. Gestures are carefully planned to coincide with the related speech part of a sentence (McNeill, 1992), thus when synchrony cannot be maintained, it may seriously impair understandability.

2) **Facilitate the planning of gesture components simultaneous with the planning of speech.**

   Gestures are produced simultaneously with speech and little attention is needed for planning and producing gestures (McNeill, 1992).
The support offered for gestures should also allow gestures to be made with minimal planning and attention. This is especially important for kinetic gestures, when the speaker’s hand (or its substitute) represent an object or person.

3) **Offer an overview of available space (which can be seen by receiver) for gesturing and the information (re)presented in this space.**
   In a face-to-face situation it is clear for all participants what can and what cannot be seen by the other participants. This may not be the case for supported face-to-face and for distributed groups. In such cases it is not only the actual visual information which is important, but also understanding the information about the world outside the room or field of view (Gaver et al., 1993). The participants must have an overview of what information is presented to the other participants, e.g., what part of the body and which basic plane (frontal or side) is shown (Gaver, 1992). This information is needed to know what gestures can be seen by the other participants and what information can be referred to.

4) **Facilitate switching between actions (e.g. between gesturing and drawing)**
   Team members switch frequently between the different types of actions, such as gesturing, writing and drawing (Tang, 1989). Switching between these actions should be easy and quick.

5) **Provide the possibility to make sequences of gestures, and gestures using two hands (or substitutes)**
   Team members also use sequences of gestures (Tang, 1991). Because these sequences can consist of different types of gestures, switching between different types of gestures should also be easy to do and instantaneous. In some cases two hands are used to convey information where each hand is needed to signify a part of the message being communicated. For example, when each hand represents an object or action, or when the space between two hands is used to indicate sizes or distances (see Figure 6.3).

6) **Allow people freedom to move around while gesturing.**
   Team members working together do not sit still. Meetings sometimes go on for hours, and sitting in one position is not comfortable or natural for such a long period of time. Participants will, for example, sit back in their chairs, lean over tables, and get up to refer to some information in the room. People should have enough space to gesture and be able to move
around the room (Gaver, 1992). This is especially important for kinetic gestures, because they often convey 3D information.

6.6.2 Specific recommendations for capturing and showing gestures

Table 6.2b
Recommendations on how to support gestures, continued (SF= supported and face-to-face, D = distributed, K= kinetic, S = spatial, P = point, and O = other).
X = primary importance, • = lesser importance.

<table>
<thead>
<tr>
<th>SF</th>
<th>D</th>
<th>K</th>
<th>S</th>
<th>P</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B Specific recommendations for making / capturing gestures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>1) Capture and show the shape and size of an object, person, or idea that is visualised with the gesture</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>2) Provide ways to mimic the actions with, or on objects, persons, or ideas</td>
<td>X</td>
<td>X</td>
<td>•</td>
</tr>
<tr>
<td>-</td>
<td>X</td>
<td>3) Preserve context information concerning sender and others</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>4) Preserve context information concerning information captured in representations</td>
<td>•</td>
<td>•</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>5) Preserve context information concerning information outside the system (in and outside the room)</td>
<td>•</td>
<td>•</td>
<td>X</td>
</tr>
<tr>
<td>-</td>
<td>X</td>
<td>6) Preserve context information concerning virtual information</td>
<td>X</td>
<td>X</td>
<td>•</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>7) Capture and show at least 2D information of gesture (preparation, acting out of meaning, to moving back to rest position)</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>8) Capture and show 3D information of gesture</td>
<td>X</td>
<td>X</td>
<td>•</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>9) Show pauses and repetitions in gestures</td>
<td>•</td>
<td>•</td>
<td>X</td>
</tr>
</tbody>
</table>

1) Capture and show the shape and size of an object, person, or idea that is visualised with the gesture

People often use their hands as 'stand-ins' for a product or an object (kinetic and spatial gestures). For example, one person in our study used one hand as a stand-in for a letter and another hand for a stamp to mimic how a letter could be franked by a machine. The shape of the hand was also be used to indicate the area referred to with a point gesture.
2) **Provide ways to mimic the actions with, or on objects, persons, or ideas**
   This is relevant for kinetic gestures. In the example for the previous recommendation the action of the stamp is mimicked by moving the hand down on the other hand representing the letter. See also the example in Figure 6.3.

3) **Preserve context information concerning sender and others**
   The gesture is interpreted using information about the person gesturing, such as the size of the person and where the sender is. For example, in Figure 6.3 the gesture also contains information about the height of the display in relation to the user using it.

4) **Preserve context information concerning information captured in representations**
   Gestures are sometimes interpreted using context information in documents or in the system. Such gestures (kinetic, spatial, and point) can only be interpreted when the listener knows to what information the speaker is referring. While this information is available in unsupported face-to-face situations, this may not be the case in the supported face-to-face and the distributed situation. For example, in our study subjects, in the supported face-to-face situation, sometimes had problems understanding to what information on the screen other team members were referring.

5) **Preserve context information concerning information outside the system (in and outside the room)**
   Gestures (kinetic, spatial and point) are sometimes interpreted using context information concerning information in the room and in the outside world. For example, the speaker in Figure 6.6 refers to information outside the room.

6) **Preserve context information concerning virtual information**
   In some cases (kinetic, spatial, and point) gestures are made to refer to information which is not physically available in the room, but which is imaginary. Such gestures can contain information about action sequences, sizes of objects and persons, and spatial relations between objects and persons. For example, the speaker in Figure 6.3 mimics the use of an imaginary weighing machine.

7) **Capture and show at least 2D information of the gesture**
   The trajectory (i.e. preparation of gesture, acting out of meaning, and moving back to rest position) contains 2D information needed to keep track of where a gesture occurs, and to be able to interpret the meaning of
the gesture. For example, a circular motion mimicking the cleaning of a
table. For "other" gestures, and for most point gestures 2D information is
enough. To keep track of where a gesture occurs listeners have to be able
to see the complete trajectory of a gesture. The importance of the different
phases varies for the different types of gestures. For kinetic and one-
handed spatial gestures the stroke usually contains the information most
important for interpreting the gesture, whereas for point and two-handed
spatial gestures the peak commonly conveys the main message.

8) **Capture and show 3D information of gesture**
   In some cases the 3D information contained in a gesture (kinetic,
spatial and point) is essential for its interpretation. For example, in our
study subjects sometimes indicated through the shape of their hand the size
of the area to which they referred in a document or on the whiteboard.

9) **Show pauses and repetitions of (in) gestures**
   Pauses (or holds) in gestures are sometimes used to attract attention,
or to emphasise a gesture (McNeill, 1992).

6.6.3 **Recommendation for displaying gestures**

Table 6.2c

Recommendation on how to support gestures, continued (SF= supported and face-
to-face, D = distributed, K= kinetic, S = spatial, P = point, and O = other).

<table>
<thead>
<tr>
<th>SF</th>
<th>D</th>
<th>K</th>
<th>S</th>
<th>P</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Recommendation for displaying gestures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>1) Offer the possibility to follow gestures actively, e.g. both speaker and listener have control over what view is captured and displayed</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

1) **Offer the possibility to follow gestures actively, e.g. both speaker and listener should have control over what view is captured and displayed.**
   This recommendation is related to recommendation 4 in Table 6.2a. If the listener wants to be able to follow what information the speaker is referring to, or what information is being shown, the listener needs to have some kind of control over what information is captured and displayed by the system (Gaver, 1992). In the supported face-to-face situation such support only applies to gestures made inside the system,
since the listener can see all gestures made outside the system, whereas in the distributed situation it applies to all gestures.

6.7 Discussion

Determining how to support the use of gestures by design teams in a supported face-to-face setting, or a distributed setting, is a difficult matter. We approached the problem by studying how gestures are used in face-to-face situations without groupware, an approach that is advised for user-centred design (e.g., Gould and Lewis, 1985; Preece, 1994). However, since the introduction of support also affects the behaviour of the associated design team it is difficult to predict how the support will eventually be used. Fortunately, part of this problem can be solved by doing early user testing of the tool to be developed, and using this information to adjust its design.

In this paper we offer a list of recommendations that can aid design tool developers in thinking about how to support gestures. We described which of the recommendations apply to each of the four types of gestures (kinetic, spatial, point and other gestures). We also discussed how these recommendations should be interpreted for supported face-to-face settings and for distributed settings. By combining the list with the results based on the actions versus activity framework a tool developer can select those recommendations that should be applied for the gestures that are frequently used during the task that is to be supported.

The list of recommendations can be used as a design aid, or to evaluate design ideas. In Bekker et al. (1995) some examples are described of limitations and weaknesses of existing (gesture) support for design teams. For example, the limited possibility of conveying kinetic gestures with a pointing device. The recommendations can be used to adjust the support to the task and to limit the weaknesses of gesture support to less frequently used gestures. Because the effectiveness of gesture support depends on many low level design decisions, it cannot be used to evaluate technologies in general, only to evaluate specific applications. For example, whether video technology supports the use of gestures well depends on many other factors, such as the video bandwidth, and camera position.

We base our list on a study of one specific task (early in the design process), and one team size (three team members). We are well aware that the use of gestures during other types of tasks, by people with different
The purposes of speech-related gestures used in design meetings

backgrounds, and in smaller or larger teams may be different. The importance of each of the characteristics, and the importance of the various gestures may vary over tasks, team compositions and team sizes. For example, we found that design teams working on a task early in the design process used gestures more frequently for design activities than for management activities (see Chapter 4). How to weigh the different recommendations and what types of gestures should be supported may vary for different situations. More research is needed to understand the use of actions during other tasks for which improved support is needed (see also Chapter 3). For example, communication with users and interactively making prototypes with other team members.

We cannot make any claim on how critical the different types of gestures are for the final design, since we have not studied the effect of not being able to gesture on the quality of the design. However, gestures were used throughout the meeting. They were often used in relation to one of the representations used (e.g. on the whiteboard, or on paper). They were very well suited to convey the complex kinetic, point and spatial information typically needed to explain design ideas. Furthermore, other studies have mentioned the problems that occur when gestures are not supported adequately. For example, the study on the use of multiple views in a media space by Gaver et al. (1993) shows that problems in explaining the spatial relation between a drawing and the room may occur when it is difficult to refer to information in the room.

Of course, people adapt to new situations and use substitute actions instead of gestures. For example, on the telephone we explain ideas in greater detail to make up for the information, such as gestures or a physical object, which we cannot show to our conversation partners. People can resort to linguistic descriptions when the gestures won't convey what they want. However, these linguistic descriptions require precious time and considerable cognitive effort to produce and to understand.

We know that groups who work in an audio-only distributed situation where the work is shared via synchronous groupware produced lower quality designs and experienced more communicative frustration than face-to-face groups using the same groupware (Olson et al., 1993, 1995). However, no quality differences were found between groups in an audio-only distributed situation, and groups in a video and audio distributed situation, nor between groups in a video and audio distributed situation and groups in a face-to-face situation (Olson et al., 1993, 1995). More research is needed to determine what the consequences are of not being
able to gesture, how the cost / benefit relation of work shifts, and whether it results in a quality difference.

We conclude that even though the list of recommendations is only a first step in the direction of understanding how gestures should be supported, it can aid developers of design support in deciding how to support gestures. Based on results of using the framework described in Chapter 5, it can assist them in making design decisions in complex design spaces.

6.8 Conclusion

The problems of supporting the various types of gestures differ for groups working in the same room and those working remotely. Kinetic, spatial and point gestures are preserved when groups work in the same room, unless they refer to information that is unavailable to the listeners. For example, when somebody refers to a drawing, but the other team members cannot see to what information in the drawing the gesture refers.

In remote settings all gestures are conveyed in a somewhat artificial way. Kinetic (e.g. how a user would use an object) and spatial gestures (e.g. how large something is) can be supported using video. Telepointers can support pointing. However, a number of difficulties arise. Some are related to the fact that the technology affects how the gestures are conveyed. The technology can distort the movement's shape making it hard to recognise and the gesture can become very small on a screen, therefore attracting less attention (Heath and Luff, 1993). The speaker may not even be aware how the gesture is presented to the recipient and then he is unable to successfully design the gesture for the appropriate response.

Other problems are related to the fact that the relation between the gesture and other information that it refers to has to be preserved, for a gesture to be understood. For example, when a point gesture refers to an object in the speakers room, but the object cannot be observed by the recipient, it will be hard to interpret.

This study has also shown that it is useful to distinguish between different types of gestures, and that the four types of gestures which were studied ask for different design considerations for support in groupware. Furthermore, if the recommendations are used in combination with the framework described in Chapter 5, the design can be tailored to specific gestures that have to be supported.
Acknowledgements
We want to thank our colleagues for their comments on earlier drafts of this chapter, and for participating in the collection and analysis of the data reported here. This work has been supported by the National Science Foundation (Grant No. IRI-8902930), and by grants from Ameritech, the Ameritech Foundation, and AT&T.
References


Appendix 1:  Questionnaire

<table>
<thead>
<tr>
<th>Questionnaire on the design of user-interfaces</th>
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</table>

This questionnaire contains questions about the design process of (telecommunication and/or) computer systems in general and user interfaces of these systems in particular.
I would be grateful if you would base your answers on a single project rather than on your general practice. The questions about the design process in particular gather information, specifically on the design of the user interface.

It is important that you base your answers on a design project:
- that has been developed for the commercial market.
- with a user-interface that will be used by an end-user and not, for example, by another computer to communicate
- where the user can interact with the user-interface.
A number of interesting applications and products would be: a word processor, electronic mail system, facsimile or a tele-shopping service.

The questionnaire consists of two parts:
I a general description of the design project: considering aspects of the application, the organisation and the design process.
II the design process
   1) constraints that were felt on design activities
   2) information sources that were used during the design process.

Some of the questions can be answered by putting a cross next to the right answer, e.g.:

What is your gender/sex?
[*] male
[ ] female

Other questions can be answered by giving a description of an aspect of the user interface.
To complete the questionnaire will take approximately three quarters of an hour.

First of all, please fill in the following:
(this information will only be used if some answers are hard to interpret)

Name : ........................................
Address : ........................................
                 ........................................
                 ........................................
Phone : .... - ........
### Part I: General description of the design project

User interfaces are being designed for a large variety of applications and systems.

Describe the design process of the project that you selected by answering the following questions:

#### 1) Application

1a) What kind of application or product has been designed (e.g. a word processor)?

1b) Describe the product functions.

1c) The type of user-interface that was designed can be described as follows: (a combination of these choices is possible)

<table>
<thead>
<tr>
<th>Dialogue style(s)</th>
<th>Interaction device(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] menu selection</td>
<td>[ ] keyboard</td>
</tr>
<tr>
<td>[ ] command language</td>
<td>[ ] function keys / soft-keys</td>
</tr>
<tr>
<td>[ ] form fill-in</td>
<td>[ ] mouse</td>
</tr>
<tr>
<td>[ ] direct manipulation</td>
<td>[ ] light pen</td>
</tr>
<tr>
<td>[ ] natural language</td>
<td>[ ] touch screen</td>
</tr>
<tr>
<td>[ ] another dialogue style, namely</td>
<td>[ ] speech recognition</td>
</tr>
<tr>
<td>[ ] another interaction device, .........</td>
<td>[ ] another interaction device, .........</td>
</tr>
</tbody>
</table>

1d) What occupation do the (prospective) users have?

1e) Describe how much computer experience the target group has:

(1) the kind and number of applications that they are experienced with.

(2) the kind and number of programming languages that they are familiar with.

1f) What will the frequency of use of the new application be?

1g) Which market was the product aimed at?

[ ] the commercial market

[ ] internal use (within the company you work for)

[ ] another use, namely ...........

1h) The application that was designed, is a

[ ] new version/release of an already existing application

[ ] a completely new application (i.e. the first version of an application)

[ ] another type of application, namely ...........
### 2) Organisation

2a) What kind of company do you work for?
- [ ] a computer or software company
- [ ] a university or a research and development department
- [ ] a non computer or software company
- [ ] as a freelance designer
- [ ] other, namely ........

2b) What kind of education have you undertaken (courses and education, etc.)?

2c) How many years of experience do you have in designing applications and user-interfaces?

2d) Did you work alone on the design project?
- [ ] yes
- [ ] no

If your answer was **yes**, please continue at question 2g).

If your answer was **no**, please continue at question 2e).

2e) How many people did the design team consist of (e.g. software engineers, and user-interface designers, etc.)?

2f) What was the role of the other people in the design team, and during which phase(s) of the design process were they active?

2g) What were your tasks during the design of the user-interface?
2h) Describe what other persons were associated with the project (e.g. customers, marketing managers, etc.) and in what way (more than one answer possible). If the involvement changes over time during the design process, you can choose more than one box for one person.

<table>
<thead>
<tr>
<th>Persons</th>
<th>Involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) client</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very much involved</td>
</tr>
<tr>
<td>2) user</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very much involved</td>
</tr>
<tr>
<td>3) marketing manager</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very much involved</td>
</tr>
<tr>
<td>4) service department</td>
<td></td>
</tr>
<tr>
<td>others,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very much involved</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>very much involved</td>
</tr>
</tbody>
</table>

2i) What was the duration of the project (e.g. available person-hours, the time span that people spent working on the project, etc.)?

2j) What kind of technological resources: hardware (e.g. PC's, Macintosh, workstations, mainframe, etc.) and software (applications and tools) were available?

3) **Design process**

3a) Give a short description of the design process of the application.

3b) During which phase(s) were you involved in the design project?

3c) Describe the situation at the time that you became involved in the project (constraints, which decisions you could still have an influence on, starting point, etc.)?
3d) How much attention had been given to the user-interface, during each of the phases of the design process (as far as you know)?

<table>
<thead>
<tr>
<th>Phases</th>
<th>Attention given</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>very much</td>
</tr>
<tr>
<td></td>
<td>attention</td>
</tr>
<tr>
<td></td>
<td>very much</td>
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<td></td>
<td>attention</td>
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<td>very much</td>
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<td>attention</td>
</tr>
<tr>
<td></td>
<td>very much</td>
</tr>
<tr>
<td></td>
<td>attention</td>
</tr>
</tbody>
</table>

3e) Describe the design process with the use of the next two scales (insert a cross on the five-point scale).

1) iterative - in phases (without feedback)

1) structure - unstructured

Depending on the situation, the process may have been either very structured or unstructured and many techniques may have been adopted or none at all. Whatever the case, this information is very relevant for my research.

3f) Were any (more or less structured) specification techniques (e.g. Task Analyses, Interaction Grammars, self developed techniques, etc.) used?

[ ] no
[ ] yes

If so, give a short description of these techniques.

3g) Were any (formal or non-formal) descriptive methodologies adopted (e.g. JSD, GOMS, self developed methodologies, etc.)?

[ ] no
[ ] yes

If so, give a short explanation.
3h) Were any prototypes made of the design concepts?
   [ ] no
   [ ] yes
   If so, during which phase(s) and how were they made?

3i) Were the concepts for the user-interface evaluated?
   [ ] no
   [ ] yes
   If so, how was it done?

3j) Did you have any notable problems during the design process?
   [ ] no
   [ ] yes, namely

3k) Did you have to make notable changes to the user-interface during the design process?
   [ ] no
   [ ] yes, namely

3l) How was the product interface finalised?
   (e.g. deadline reached, premature finalization, no more money left, etc.)

3m) What would you have done differently with the benefit of hindsight?
   [ ] nothing
   [ ] the following, ...........

3n) To what extent were the following people satisfied with the final user-interface?

1) yourself satisfied

Reason(s):

2) client satisfied

Reason(s):

Others:

................. satisfied

Reason(s):

................. satisfied

Reason(s):

3o) Any additional information that you consider relevant you can write down below.
**Part II: The design process**

This part of the questionnaire gathers information about the design process itself. You are asked to make lists of the constraints that were experienced and the information sources that were used during the design process that you have selected to describe.

**1) Constraints that were experienced during the design process**

A constraint in this case may be anything which impedes or prevents a design team from progressing in what they perceive to be an ideal manner towards their design goal.

1a) Please read the following list of constraints that may influence design activities concerning the user-interface.

   a) lack of guidance from parties outside of the design team (e.g., client, marketing department, etc.).
   b) lack of autonomy from parties outside of team
   c) lack of authority to make design decisions
   d) oversized team
   e) undersized team
   f) undefined team member roles
   g) over-rigid team member roles
   h) lack of assistance / collaboration of the client
   i) client over-intervention
   j) lack of information about tasks
   k) lack of information about users
   l) over-casual approach to design
   m) over-rigid approach to design
   n) over-casual approach to evaluation
   o) over-rigid approach to evaluation
   p) lack of experience in human-computer interaction
   q) lack of experience with interface design
   r) lack of familiarity of application domain
   s) complex application / sophistication of product
   t) inadequate resources (e.g., time, money, equipment, etc.)
   u) lack of communication / collaboration between members of the team and / or consultants

1b) Please rank the constraints that you have experienced in descending order of importance (i.e. 1 is the most important). Give a short explanation about how these constraints influenced the design process.

It is possible that during the project some of the items in the list were not considered to be a constraint. However, on comparing the situation then with an ideal design situation some of these items may after all be judged to be a constraint. Would you please add these items as well, indicating that you did not consider them until after the project was compared to an ideal situation.
(Please refer to each item above by its reference letter)

<table>
<thead>
<tr>
<th>Rank no</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4. etc.</td>
<td></td>
</tr>
</tbody>
</table>

1c) Any constraints which were experienced and have not been included in the list, may be listed below. These extra constraints should also be ranked in the following way, e.g. between no. 1 and 2, or e.g. it is the most important constraint, and thus has to be placed before 1 in the ranked list in question 1b.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Extra constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>-&gt; 1b</td>
<td></td>
</tr>
</tbody>
</table>

|               |               |
|               |               |
|               |               |
|               |               |
2) Information that was used during the design process

2a) During the design process information can be gathered in many different ways and from many different sources. Please read the following list which could be during the design process of the user-interface. Rank the information sources that you have used for your particular design project in descending order of importance (1 is the most important).

NB: It is possible that some of these information sources were not consulted during your project, but that you used this knowledge inadvertently (e.g. because you have consulted one of these sources for a previous project and you used the knowledge automatically). These information sources should also be mentioned.

a) scientific / psychological references on human behaviour, etc.
b) psychological or human-computer-interaction task analyses of related activities
c) surveys / reports on human characteristics
d) documentation on related activities (e.g., teaching material, manuals)
e) surveys / reports on target user-groups
f) specifications of to-be-supported activity.
g) studying / analysing similar applications or products
h) interviews with non-prospective-users about user group characteristics
i) interviews with prospective users about their characteristics
j) verbal task descriptions from current activity performers
k) verbal task descriptions from other persons
l) observation of prospective user activity
m) observation of non-prospective user activity
n) observation of activity independent of prototype use
o) observation of activity using a prototype
p) experimentation / testing with prospective users
q) experimentation / testing with non-prospective users
r) experimentation on prospective user activity with prototype
s) experimentation on prospective user activity without prototype (i.e., a simulation without functionality, e.g. a mock-up)
2b) Give a short explanation of where you got the information from (e.g. your education or a library, etc.) and how you have used it.

(Please refer to each item above by its reference letter)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>no</td>
<td>letter</td>
</tr>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>etc.</td>
</tr>
</tbody>
</table>

2c) Any information sources which have been used and have not been included in the listing above may be ranked below in the same manner as in question 1c.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Extra constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>-&gt; 1b</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Many thanks for your time. Would you please send the questionnaire back to me in the reply-envelope?

Yours sincerely,

Ir. Mathilde Bekker
T.U. Delft, Fac. of Industrial Design Engineering
Jaffalaan 9
2628 BX Delft
tel: 015 - 784218
Appendix 2: Interview scheme

Name subject : 
Company or affiliation : 
Date of interview : 
Time of interview : 
Place of interview : 

General introduction
- aim: to gather information about the design of user interfaces in practice:
  * results previous research
  * more detailed information
- selection of subjects: designers of user interfaces in the Netherlands working for
  various employers.
- length of interview: approximately one and a half hours
- do you object to us making a video recording of the interview?
- the information will be treated as confidential:
  * no mention of names of subjects and products designed, etc.
- do you have any questions before we go on?

Part 1: Six aspects of the design process

Introduction
1. Can you give examples of some products or systems you have designed?
   (preferably one with major user interface design)

2. Which of these examples would you select as a typical design project with which
   you have been involved?

3. Could you give a general description of the project:
   - product or system
   - history of design: redesign / innovation / other, namely .......
   - complexity of the product
   - number of people involved
   - client / person initiating the project
   - length of project (time and person hours)
   - involvement during which phases

Before you start answering the questions we would like you to observe the
following:
- when answering the questions consider only one typical design project in which
  you were involved
- we will be giving you statements we want to exchange ideas about.

With each statement we would like you to give your experiences.
I Usually a number of people are involved in a design project. Some people are part of the actual design team, whereas others are used as consultants.

(lack of guidance)

INTERPRETATION
Would you please answer the following questions:
1a) Have you worked with other people during the project you have selected?
   If not, go to part 4.2 division of tasks
   If so,
   - number of people involved
   - backgrounds of the people involved
   (education / experience)

1b) How did the people involved in the project collaborate?
   - who was really involved
     * in the team
     * client / experts / marketing department / management / technical
       experts / programmers
   - who was “only” consulted
     * client / experts / marketing department / management / technical
       experts / programmers
   - what kind of advise did you seek:
     * about users / technical aspects / functionality / existing applications

1c) Which people belonged to the actual team, and which were not really part of the team, but were consulted during the project?

1d) Were you satisfied with the collaboration between the people involved in the project? (positive statements)
   * people were always available / enough expertise / clear task division

1e) Would you have liked to have seen things go differently?
   (negative statements)
   * changing opinions / changing information / too little explanation

CONSEQUENCES
2a) Compare the situation (collaboration) during this design process and the situation during other design processes in which you have been involved. Was the design project you selected different in a significant way than the other design projects you have worked on?
   If so, what was different?

2b) What kind of consequences did the situation you described have for the progress of the project?
(positive and negative statements)
- progress
- work motivation
- available information
- final product of the process

GIVE AN OVERVIEW OF THE ANSWERS TO THIS PART

SOLUTIONS
3a) How do you think the process could be improved?
- existing techniques
- new solutions

II As a consequence of the collaboration between the team members there will always be some kind of task division and decision structure for a project: E.g., these can be very formal and hierarchical or they can be very informal and the responsibility can be shared.

Many people have to work together in a team and these people will sometimes agree, and sometimes disagree.

INTERPRETATION
1a) How were decisions made during the design project?

1b) Who had a say in things?
* team members / management / experts / marketing / technicians / client

1c) Who made decisions when more than one solution was available?
* team members / management / experts / marketing / technicians / client

1d) Was it possible to change decisions in later stages of the design process?
If so, or If not

1e) Were decisions made explicitly?

1f) Who was responsible for each of the parts of the design?

1g) Was it clear who had a say in each of the design aspects?
* areas
* who thought so?

1h) Based on what information were decisions usually made?
* how much "evidence" was needed?

1i) What was your role in this set-up?
CONSEQUENCES
2a) Compare the way the tasks were divided and how decisions were made in this project with how this was organised during other projects in which you have been involved. Was this project different from other projects you have been involved in?

2b) What consequences have these differences had for the design project?
- progress
- making decisions
- sticking with decisions
- "consistency" of design
- time spent on each of the design phases

------- GIVE AN OVERVIEW --------

SOLUTIONS
3a) How do you think the process could be improved?
- existing techniques
- new solutions

| III | The application being designed can either be a redesign of an earlier design or can be a completely new design. In some cases a lot of knowledge is available about the application domain in the company, but in other cases it is much more difficult to find such information. |

INTERPRETATION
1a) Did you have information about the application domain?
   If not, go to topic 4.4. complexity
   If so,
   a.1) Who had the knowledge?
       Team member / domain expert / external expert

   a.2) How much knowledge?

   a.3) In what form?
       * documentation
       * having developed something for the same domain before

1b) Did you have enough information about the application domain?

  If not,
  b.1) What information was missing?
       * user / task / technical information / tools / marketing
       * detail / more general

  WHY / CAUSES OF LACK OF INFORMATION
  b.2) Why do you think that too little information was available?
       - too little time / money / resources
- functionality was not yet known
- new to company
- innovative

1c) Did you know of similar applications that could have been studied as a comparison?

CONSEQUENCES
2a) Compare the amount and applicability of information about the application domain in the project you have chosen, with that in other projects.

2b) What consequences did the lack of information have for the project? (positive and negative)
  - available time for development
  - gathering useful information
  - progress

---------- GIVE OVERVIEW ---------

SOLUTIONS
- existing solutions?
- new solutions?

**IV Applications that are being developed differ in the level of complexity.**

INTERPRETATION
1a) What was the level of complexity for the application being developed in the project we are discussing in this interview? E.g., by comparing it to another application that you have developed.

1b) What aspects make an application complex to develop?
  * APPLICATION / USER INTERFACE
    - number of functions / functionality
    - number of tasks
    - multi purpose versus single purpose
  * DESIGN PROCESS
    - unknown area for designer
    - innovation

CONSEQUENCES
2a) What were the consequences of the level of complexity for the design process? Compare it with other design processes with more or less complex applications. (positive and negative)
  - available time for development
  - information needed: user / task / technical / tools / marketing
  - number of iterations
  - length of phases: information gathering / detailed design / prototyping / evaluation / implementation
--------- GIVE OVERVIEW ---------

SOLUTIONS
- existing solutions
- new solutions

V In some design projects the prospective user group is known from the start, whereas in other projects the user group is (re-) defined at a later phase in the project.

INTERPRETATION

1a) Could you tell us how and when this decision was made in your project?

1b) Did you have enough information about the prospective users?
   early phases / middle phases / late phases

1c) How was the information about the users gathered?
   - techniques: interviews / observation / reports
   - number of subjects

1d) Were you satisfied with the amount and type of information that you had available?
   If so, go to question 1e.
   If not,
   d.1) What information was missing?

CAUSES:
   d.2) What were the reasons that you did not have enough information about the users?
   - too little time / money / resources
   - not being able to contact the users
   - users unknown / not yet defined
   - prospective users redefined during the process
   - hard to get useful information from users themselves

1e) How did you use the knowledge about the users in the design process?

CONSEQUENCES

2a) What were the consequences of (the lack of information) for the project?

Compare this situation with other projects.
(same amount of information available / prospective users known)
   - adapt design
   - applicability of information during design process
   - interpretation of available information

--------- GIVE OVERVIEW ---------
SOLUTIONS
- existing solutions
- new solutions

VI A design project usually has certain resources in time, money and the available hard- and software (tools, PC's, etc.).

1a) Could you tell us what and how extensive the resources were available during your project?

CAUSES

a.1) Time
    - planning  - communication
a.2) Money
    - budget    - costs
a.3) Resources
    - equipment - appropriate hard- and software
    - enough equipment available on the market

CONSEQUENCES
3a) What were the consequences of the availability of resources for the project?
   Comparison with other projects.
   a.1) time
        for developing a concept / prototyping / evaluating
   a.2) money
        equipment / consulting experts
   a.3) resources
        equipment for evaluating / prototyping / implementing design

---------- GIVE OVERVIEW ----------

SOLUTIONS
- existing solutions
- new solutions
Part II: The ideal design process

Introduction
In this part of the interview we would like to discuss what an ideal design process would be like. In a real-life design project there are always a number of aspects that we cannot influence. Imagine a design project during which you could determine what it would be like.
CHECK: - methods / tools / techniques / activities - all design phases

1. At Delft University of Technology research is conducted on design method and techniques. What design method or technique do you think we should be developing?
   Phases:                       Topics discussed:
   1) gather information       1) collaboration and task division
   2) idea generation          2) power
   3) detailed design          3) knowledge of application domain
   4) prototype                4) complexity of application
   5) evaluation               5) information about user
   6) implementation          6) resources

Do you want to add something to one of the answers that you have given?

What did you think of the interview?

Thank you very much for your cooperation!
Appendix 3: Automatic Post Office Task

The Automatic Post Office
(1-1/2 hours)

You are employees of a new company of thirty people with an idea for a new integrated product. It is a standalone, unmanned post office that is similar in concept to a bank automatic teller machine, in that it offers some of the services that you can get in the manned post office and it is open 24 hours a day, 7 days a week.

You would like to develop a working prototype to present to the postal authorities at the end of 12 months.

You are now to spend an hour and a half beginning to put together a plan for what this post office would do --- what services would be offered and in general how it would work (meaning what kinds of equipment you would include, what other people would have to be involved to service the place, etc.).

Consider the cost of the facility as well as arguments to the post office about the benefits for having it.

Make sure you do not suggest anything for which a prototype could not be built in a year.

An hour and a half is clearly not enough time to consider this whole design. Do as much as you can, and in the course of doing this:

make notes about the ideas you have thought of, and things you would like to investigate before you meet again, if you were going to meet again on this.

As output of this meeting, we would like you to write your ideas in sentences or phrases in a brief form that can be understood by someone who knew in general what you were doing but wasn't at the meeting.
## Appendix 4: Rules for coding the design meeting activities

### Table A.1
*Categories of design meeting activities. Divided into procedural activities, design activities and other activities (according to Storøstøen, 1993).*

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>Statement of purpose of the group's meeting and some of the constraints they are to work under, such as time to finish or motivating statements about how important this is.</td>
</tr>
<tr>
<td>Meeting Management</td>
<td>Statements having to do with orchestrating the meeting time's activity, indicating that the group members are to brainstorm, decide (and vote), hold off on a discussion, etc.</td>
</tr>
<tr>
<td>Project Management</td>
<td>Statements having to do with the activity not directly related to the content of the design, in which people are assigned to perform certain activities, decide when to meet again, report on the activity (free of design content) from previous times, etc.</td>
</tr>
<tr>
<td>Summary</td>
<td>Reviews of the state of the design or implementation to date, restating issues, alternatives and criteria. It is a summary if it is a simple list-like restatement. If it is ordered by steps, it is a walkthrough, defined next.</td>
</tr>
<tr>
<td>Technology Management</td>
<td>These are statements that request or suggest how the group members use or organise themselves in using the technology.</td>
</tr>
<tr>
<td>Writing Management</td>
<td>These are statements that seek to organise the writing process, either dictating what to write or saying out loud what one is going to write.</td>
</tr>
<tr>
<td>Design Issues</td>
<td>The major questions, problems, or aspects of the designed object itself that need to be addressed. They typically focus on the major topics of &quot;shall we offer this capability to the user?&quot; and &quot;how can we implement that?&quot;. Included in the time is the elaboration of the idea, description not in the answer to a group member's question.</td>
</tr>
</tbody>
</table>

Occasionally, the issues are not stated explicitly but can be inferred (both by the coder and by members of the design meeting) by the presentation of two alternative solutions. These are counted as short statements of issues, typically marking the first part of the sentence that presents the alternatives.
Alternatives  Solutions or proposals about aspects of the designed object. These are typically either features to offer the user or ways to implement the features decided on so far. Included in the time is the elaboration of the idea, description not in answer to a group member's question. Occasionally, there is an elaboration, usually the implications of the idea just presented, that is also included in this category.

Criteria  The reasons, arguments, or opinions which evaluate an alternative solution or proposal. Occasionally these appear in the form of analogous systems, with the implication that if it worked in this other system it would be good for this system. Occasionally, an evaluative statement or criterion will be made unconnected to any particular alternative, in the background, so that members of the group are reminded to evaluate the upcoming or past proposed solution in the light of it.

Walkthrough  A gathering of the design so far or the sequence of steps the user will engage in when using the design so far, used either to review or clarify a situation. It usually follows the user's task, the flow of data or messages inside a system's architecture.

Other

Digression  Members joking, discussion side topics (e.g., how to get the computer to make dotted line), or interruptions having to do with things outside the content of the meeting (e.g., discussion of why the plant was moved over by the window, or that it is beginning to snow and they should leave early today). When the person running the experiment speaks, it is considered a digression.

Other  Statements not categorizable in any of the above categories. For example, in one meeting the team members discussed how their coordination was insufficient in the past; in another the group members spent a large amount of time searching within the computer for the answer to a question of whether a language could support a particular function.

Technology Confusion  Comments on using the shared editor, such as conflicting selections of text and problems remembering commands, other than how to organise their work.
### Appendix 5: Rules for coding gesture categories

**Table A.2**  
*Categories of gestures and descriptions on how to code them.*

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Kinetic** | These gestures usually show the behaviour of the product or the user. The gesture is usually related to the verb in the sentence that is simultaneously voiced. The movement executes all or part of an action performance. These gestures are often compound gestures. In some cases these gestures show the ongoing process.  
E.g. making a circle gesture to depict the iterations in the design process. |
| **Spatial** | The movement of the gesture indicates distance between people, objects or ideas or the size of some object. In some cases the gesture shows the distance between more than two people, objects or ideas, and then it looks like a repetitive gesture.  
E.g. A room with four little windows  
(gesture: 1 -> 1 -> 1 -> 1)  
When subjects describe two or more contrasting concepts (e.g., this one or the other one), the gestures are coded as **point** if the subject points to these (abstract) concepts, they are coded as **spatial** if the subject indicates the size or shape (abstract) concepts (with two hands). |
| **Point** | Some part of the body, usually fingers or a hand, point to some person, to some part of the body, to an object or place. Or, the referent may be a more abstract attitude, attribute, affect, direction, or location. The gesture often is related to words such as this, that or there.  
E.g. in some cases a collection of pointing gestures are used to count items of a list on the fingers of a hand.  
When subjects describe two or more contrasting concepts (e.g., this one or the other one), the gestures are coded as **point** if the subject points to these (abstract) concepts, they are coded as **spatial** if the subject indicates the size or shape (abstract) concepts (with two hands). |
| **Other** | All gestures that do not fall into one of the first three categories fall into this category.  
E.g. gestures that are used to emphasise parts of a sentence or to attract attention.  
When a point, spatial or kinetic gesture is repeated for emphasis the gesture should be coded as **other**. E.g. when a subject talks about items of a list and points to his fingers by way of counting, the gesture should be coded as point when the gesture is related to a new item on the list, but coded as other if the gesture is used for emphasis.  
When subjects are listing a number of items and count using their fingers without pointing to them with the other hand, these gestures will be coded as "**other**". |
Appendix 6: Agreement on gesture coding scheme

In the present study agreement can be described as a two step process. The first step consists of determining whether a gesture occurs, and the second step involves determining what type of gesture has occurred. The first step of this process introduces an extra category to be included in the agreement matrix: none (no gesture).

The cell representing the cases where both coders coded no gesture, is hard to define. In each cell ij represents the number of gestures that coder A coded as category i and coder B coded as category j. We can count the number of clauses for which the coders agreed no gesture occurred, but the number of gestures on which the coders agreed were not made is undefined.

The number of clauses in the transcript was 1793. No gestures were coded in 883 clauses, whereas in 910 clauses either one or both coders coded a gesture.

Table A.1
The agreement matrix for the coding of the gestures by two coders. (Coder A on the horizontal axis, and coder B on the vertical axis). The number of gestures in which the coders agreed is given on the diagonal of the matrix. The cell none - none is undefined (x).

<table>
<thead>
<tr>
<th></th>
<th>none</th>
<th>kinetic</th>
<th>spatial</th>
<th>point</th>
<th>other</th>
<th>Total number of gestures</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>x</td>
<td>13</td>
<td>6</td>
<td>40</td>
<td>49</td>
<td>x + 108</td>
</tr>
<tr>
<td>kinetic</td>
<td>10</td>
<td>178</td>
<td>3</td>
<td>17</td>
<td>21</td>
<td>229</td>
</tr>
<tr>
<td>spatial</td>
<td>14</td>
<td>7</td>
<td>82</td>
<td>20</td>
<td>22</td>
<td>145</td>
</tr>
<tr>
<td>point</td>
<td>16</td>
<td>3</td>
<td>0</td>
<td>139</td>
<td>38</td>
<td>196</td>
</tr>
<tr>
<td>other</td>
<td>131</td>
<td>13</td>
<td>17</td>
<td>53</td>
<td>450</td>
<td>664</td>
</tr>
<tr>
<td>Total number of gestures</td>
<td>x + 171</td>
<td>214</td>
<td>108</td>
<td>269</td>
<td>580</td>
<td>x + 1342</td>
</tr>
</tbody>
</table>

Coder A coded 1234 gestures, and coder B coded 1171 gestures. Of the 1342 gestures that were coded, 849 were agreed upon by the coders (63%).
Table A.2
The agreement matrix given the fact that both coders agreed that a gesture occurred. Coder A on the horizontal axis, and coder B on the vertical axis. The number of gestures in which the coders agreed is given on the diagonal of the matrix.

<table>
<thead>
<tr>
<th></th>
<th>kinetic</th>
<th>spatial</th>
<th>point</th>
<th>other</th>
<th>total number of gestures</th>
</tr>
</thead>
<tbody>
<tr>
<td>kinetic</td>
<td>178</td>
<td>3</td>
<td>17</td>
<td>21</td>
<td>219</td>
</tr>
<tr>
<td>spatial</td>
<td>7</td>
<td>82</td>
<td>20</td>
<td>22</td>
<td>131</td>
</tr>
<tr>
<td>point</td>
<td>3</td>
<td>0</td>
<td>139</td>
<td>38</td>
<td>180</td>
</tr>
<tr>
<td>other</td>
<td>13</td>
<td>17</td>
<td>53</td>
<td>450</td>
<td>533</td>
</tr>
<tr>
<td>total number of gestures</td>
<td>201</td>
<td>102</td>
<td>229</td>
<td>531</td>
<td>1063</td>
</tr>
</tbody>
</table>
Samenvatting

Een analyse van de user-interface ontwerppraktijk
Aanbevelingen voor de ondersteuning van communicatie in ontwerpgroepen

Mathilde M. Bekker

Introductie
Het gedeelte van het produkt of computersysteem waarmee de gebruiker interacteert (i.e. user interface) bepaalt voor een belangrijk deel of een produkt of computersysteem gebruiksvriendelijk is. Het ontwerpen van user interfaces voor zowel consumentenprodukten als voor computerprogramma's is een complex proces. Een ontwerper moet zeer uiteenlopende aspecten (zoals de kostprijs, ergonomie, de stand van de techniek, constructie en marketing) afwegen en combineren om tot een goed eindproduct te komen. Nieuwe technologische ontwikkelingen, zoals multi-media (het gebruik van verscheidene invoer- en uitvoermedia zoals geluid, tekst en video) bieden nieuwe mogelijkheden voor te ontwerpen user interfaces. Het integreren van deze nieuwe mogelijkheden, zodat het uiteindelijke user interface gemakkelijk te bedienen is, blijft een uitdaging voor user interface ontwerpers.

Er worden veel ontwerphulpmiddelen aangeboden om user interface ontwerpers te ondersteunen in dit complexe proces. Om ondersteuning te kunnen ontwikkelen die een positieve bijdrage levert aan het ontwerpprocess is het echter belangrijk om te weten wie dergelijke hulpmiddelen gebruikt en in welke context ze gebruikt worden. De algemene vraagstelling die we in dit proefschrift bestuderen is wat voor nieuwe of verbeterde hulpmiddelen (b.v. ontwerpmethodes, of andere ondersteunende gereedschappen) user interface ontwerpers kunnen helpen bij het ontwerpen van gebruiksvriendelijke user interfaces.

Onze onderzoeksanpak is geïnspireerd door de user-centred ontwerpmethod (een ontwerpmethod waarbij de gebruiker een centrale rol speelt in het ontwerpprocess). User-centred ontwerpen is een iteratief proces. De eerste stap in het user-centred ontwerpen bestaat uit het verzamelen van informatie over de gebruiker en de gebruikscontext, om te begrijpen wie de gebruiker van het te ontwerpen produkt zal zijn en in welke context het produkt gebruikt zal worden. Vervolgens wordt een produkt of applicatie voor en vaak zelfs met de gebruiker ontworpen. Daarna wordt het gebruik van het ontwerp door de gebruiker
geëvalueerd. Elke iteratie kan leiden tot een nieuw ontwerpvoorstel, tot een geheel nieuw produkt of tot een herontwerp van een al bestaand produkt.

De user interface ontwerppraktijk
We hebben ons onderzoek op eenzelfde manier aangepakt. Het doel van onze eerste studie was te bepalen wie degenen zijn die de user interface ontwerphulpmiddelen gebruiken in de praktijk, en hoe ontwerpprojecten er in de praktijk in Nederland uitzien. Eerder onderzoek heeft geresulteerd in kennis over de ontwerppraktijk. Bij deze studies lag de nadruk op onderzoek naar zeer grote ontwerpprojecten. De mensen die daarover ondervraagd zijn, waren vooral systeemontwerpers en programmeurs. In dit proefschrift richten we ons op kleine tot middelgrote projecten en welke mensen user interfaces ontwikkelen.

In Hoofdstuk 2 wordt een studie beschreven waar we enquêtes hebben voorgelegd aan mensen die bij de ontwikkeling van user interfaces zijn betrokken. Het doel van deze studie was te bepalen wie de gebruikers (b.v. achtergrond en functie) van ontwerphulpmiddelen zijn en in welke ontwerpcontext (b.v. type project, soort produkt dat wordt ontworpen en grootte team) ze meestal werken. Aan de ontwerpers werd gevraagd om hun praktijkervaringen te beschrijven en om hun antwoorden te baseren op een recentelijk afgerond project. Uit de resultaten blijkt dat de ontwerppraktijk zeer gevarieerd is. Daardoor lijkt het niet mogelijk om ondersteuning voor het user interface ontwerpproces op een zodanige manier af te stemmen op een specifieke ontwerpsituatie dat het door een brede gebruikersgroep bruikbaar zal zijn. Tevens blijkt uit de resultaten dat er twee gebieden zijn waarvoor ondersteuning verbeterd kan worden: 1) hoe ontwerpers informatie over gebruikers moeten verzamelen en 2) de manier waarop taken worden verdeeld en beslissingen worden genomen in het ontwerpproject.

Behoeften van user interface ontwerpers
Nadat we hadden onderzocht wie de gebruikers van ontwerphulpmiddelen zijn, stelden we de onderzoeksvraag voor onze volgende studie vast: met behulp van wat voor ontwerphulpmiddelen kan de ondersteuning van het ontwerpproces verbeterd worden?

In Hoofdstuk 3 beschrijven we hoe user interface ontwerpers geïnterviewd zijn over hun ervaringen in de praktijk. Tevens is aan de ontwerpers gevraagd wat voor soort hulpmiddel volgens hen het ontwerpproces zou kunnen verbeteren. Om ervoor te zorgen dat de resultaten niet vertekend
worden door een specifieke ontwerpsituatie hebben we ontwerpers die in verschillende ontwerpsituaties (b.v. computerbedrijven, produktontwikkeling en onderzoeksinstituten) werken gevraagd om mee te werken aan de interviews. We hebben onderzocht wat voor problemen ze ervoeren tijdens de ontwerpprojecten en met behulp van wat voor ondersteuning deze problemen voorkomen of weggenomen zouden kunnen worden.

Uit de resultaten (genoemde problemen en gewenste ondersteuning) bleek dat ontwerpers ondersteuning nodig hebben voor het maken van prototypes van de user interfaces en voor het communiceren met andere mensen (zoals gebruikers, managers en opdrachtgevers) die bij het ontwerpproject betrokken zijn. Het bespreken van ontwerpideeën met andere mensen die bij het project betrokken zijn bleek heel belangrijk te zijn gedurende het gehele ontwerpproject. Het verzamelen van informatie over gebruikers en hun taken was een van de activiteiten waarvoor volgens de ontwerpers de ondersteuning verbeterd kan worden. De belangrijkste redenen die werden gegeven voor de problemen met het verzamelen van deze informatie waren:
• geen toestemming krijgen van de opdrachtgever om de gebruiker te benaderen omdat men bang was dat er informatie naar een concurrent zou uitlekken.
• niet weten m.b.v. van welke methode de informatie over de gebruiker het beste verzameld kan worden.
• te infrequent contact met de gebruikers gedurende het project.

Een aanverwante activiteit waarvoor ontwerpers een betere ondersteuning vroegen was het aanbrengen van veranderingen in een prototype terwijl het ontwerp wordt besproken. Prototypes kunnen worden gebruikt om het ontwerp uit te leggen, om feedback te krijgen over het ontwerp van allerlei mensen die betrokken zijn bij het ontwerpproces, waaronder gebruikers, programmeurs en opdrachtgevers.

Omdat communicatie een activiteit is die gedurende het gehele proces als zeer belangrijk wordt ervaren en omdat communicatie gezien kan worden als een laag over alle andere ontwerpectiviteiten, hebben we de context van de communicatieproblemen nader onderzocht. Uit de resultaten van de interviews bleek dat ontwerpoplossingen besproken worden met diverse mensen die bij het project betrokken zijn, b.v. om extra informatie te verzamelen, om het ontwerp uit te leggen of om te beslissen wat de volgende stap in het ontwerpproces zal zijn. Bovendien werden er veel redenen genoemd waarom communiceren niet altijd succesvol was. In sommige gevallen traden er problemen op omdat leden van het
ontwerpteam verschillende soorten representaties (b.v. documenten, tekeningen en prototypes) gebruiken. In andere gevallen werden de problemen veroorzaakt door het feit dat leden van het team niet allemaal dezelfde terminologie gebruikten.

Communicatie in ontwerpteam
Uit de interviews bleek waardoor communicatieproblemen kunnen ontstaan in de ontwerppraktijk. Het doel van de studie die in de Hoofdstukken 4 en 5 van het proefschrift wordt beschreven was om aanbevelingen af te leiden met betrekking tot hoe communicatie in ontwerpteam kan worden ondersteund. In dit proefschrift hebben we besloten, m.n. vanwege praktische redenen zoals beschikbaarheid van proefpersonen en tijd, dat we communicatie in homogene teams zouden bestuderen. We waren met name geïnteresseerd in hoe teamleden over hun ontwerpideeën communiceren, en daarom hebben we ontwerpbesprekingen bestudeerd waarin ontwerpideeën werden besproken.

Van de verschillende acties die ontwerpteam gebruiken om te communiceren, zoals praten, schrijven, tekenen en gebaren maken, heeft het maken van gebaren tot nu toe nog slechts weinig aandacht gekregen. Case studies hebben aangetoond dat het moeilijk is om gebaren via groupware hulpmiddelen (software voor gebruik door meer dan één persoon, b.v. e-mail software) over te brengen. Gebaren hebben een aantal eigenschappen waardoor ze heel aantrekkelijk zijn voor communicatiedoeleinden: ze vragen weinig mentale inspanning, het kost weinig tijd en moeite om ze te maken, ze kunnen simultaan met spraak gemaakt worden en ze kunnen complexe informatie op een zeer compacte manier over brengen. In onze laatste studie, die in de Hoofdstukken 4 en 5 staat beschreven, hebben we bestudeerd hoe gebaren door ontwerpers in ontwerpbijeenkomsten gebruikt worden.

Ook hier beschouwen we het onderzoek als een user-centred ontwerpproces. We gaan ervan uit dat we beter begrijpen hoe men communiceert in de huidige situatie, dat we deze kennis kunnen gebruiken om aanbevelingen te doen zodat de ondersteuning van communicatie d.m.v. hulpmiddelen verbeterd kan worden. We onderscheiden vier typen gebaren: kinetische- (het uitbeelden van acties), spatiële- (het uitbeelden van afstanden tussen mensen, objecten en ideeën), referentie- (het refereren aan een object, persoon of idee) en overige gebaren (de rest, waaronder het benadrukken van een deel van de zin).
Het doel van de studie is te bepalen voor welke taken elk van de vier typen gebaren gebruikt wordt en om te bepalen of ondersteuning voor gebaren aangepast kan worden aan de taak. Meer specifiek zijn we erin geïnteresseerd of gebaren vaker voor ontwerpectiviteiten (b.v. uitleggen hoe het ontwerp werkt) dan voor management activiteiten (b.v. bepalen wie welke taak gaat uitvoeren) gebruikt worden. We wilden tevens bepalen hoe het gebruik van gebaren wordt beïnvloed door de hulpmiddelen die de groepen ter beschikking hadden. Daarom hebben we bestudeerd hoe gebaren gebruikt worden door groepen die basishulpmiddelen zoals pen, papier en een schrijfbord gebruiken en door groepen die meer geavanceerde hulpmiddelen gebruiken, namelijk een tekstverwerker, die tegelijkertijd door alle leden van een groep gebruikt kan worden. Om te bepalen welke gebaren werden gebruikt voor elk van de activiteiten, hebben we een acties (vier typen gebaren: kinetische-, spatiële-, referentie- en overige gebaren) versus activiteiten (ontwerp-, management- en overige activiteiten) schema gebruikt, waarin het aantal gebaren per seconde werd genoteerd.

Uit de resultaten van Hoofdstuk 4 blijkt dat gebaren gebruikt worden voor alle drie de soorten activiteiten (ontwerp-, management- en overige activiteiten). Kinetische-, spatiale- en overige gebaren worden vaak gebruikt voor ontwerpectiviteiten, terwijl referentiegebaren zeer frequent worden gebruikt voor zowel ontwerp- als managementactiviteiten. De groepen die pen, papier en het schrijfbord ter beschikking hadden, gebruikten gemiddeld meer gebaren dan de groepen die de tekstverwerker gebruikten. Het verschil werd vrijwel geheel veroorzaakt door het feit dat de groepen die pen, papier en het schrijfbord gebruikten meer referentiegebaren per seconde gebruikten voor managementactiviteiten. Tevens bleek dat gemiddeld over alle groepen meer gebaren voor ontwerp- dan voor management activiteiten werden gebruikt. Dit betekent dat een ontwerp van een gebaarondersteunend hulpmiddel aangepast kan worden aan de taak die moet worden verricht.

Ondersteuning voor gebaren
Nadat we hadden bepaald wat voor typen gebaren tijdens ontwerpbesprekingen gebruikt, hebben we tevens onderzocht hoe gebaren moeten worden ondersteund (zie Hoofdstuk 5). We hebben twee aspecten bestudeerd. Ten eerste, hebben we onderzocht wat de karakteristieke eigenschappen van de verschillende soorten gebaren zijn die van belang zijn om de informatie die in het gebaar is vastgelegd over te dragen. Op deze manier hebben we bepaald of verschillende soorten
gebaren op verschillende manieren kunnen en moeten worden ondersteund. Ten tweede, hebben we onderzocht wat de verschillen zijn tussen het gebruik van gebaren tijdens vergaderingen zonder computerondersteuning waarbij de teamleden zich in dezelfde ruimte bevinden, vergaderingen met gebruik van computerondersteuning waarbij de teamleden zich in dezelfde ruimte bevinden, en vergaderingen met gebruik van computerondersteuning waarbij de teamleden zich op verschillende locaties bevinden. Op deze manier hebben we een lijst met aanbevelingen opgesteld voor het ondersteunen van gebaren in deze situaties.

Uit de resultaten van Hoofdstuk 5 volgt dat gebaren voor zeer uiteenlopende doeleinden worden gebruikt. Kinetische gebaren worden gebruikt om de interactie weer te geven tussen de gebruiker en het produkt. Referentiegebaren worden vaak gebruikt om te refereren aan informatie over het ontwerp. Bovendien is voor de verschillende typen gebaren een ander deel van de beweging het meest relevant voor de interpretatie. Bijvoorbeeld, voor kinetische- en spatiële gebaren is de 3D informatie van het gebaar erg belangrijk, terwijl voor referentie- en "overige" gebaren 2D informatie meestal genoeg is. Het belang van de verschillende fasen van de gebaren (b.v. de voorbereidings-fase, het eigenlijke gebaar, en de terug-trek-fase) verschilt ook van type gebaar tot type gebaar. Voor kinetische gebaren en spatiële gebaren die met één hand worden gemaakt, bevat het eigenlijke gebaar meestal de belangrijkste informatie om het gebaar te interpreteren, terwijl bij referentie en spatiële gebaren, waarbij twee handen worden gebruikt, een klein onderdeel van het eigenlijke gebaar meestal de belangrijkste informatie bevat.

Vervolgens hebben we drie problemen beschreven die spelen bij het computerondersteunen van gebaren: 1) het behoud van de relatie tussen het gebaar en datgene waaraan het refereert, 2) de vertekening van het gebaar als gevolg van de technologie die wordt gebruikt om het gebaar over te brengen, en 3) de onduidelijkheid voor de spreker over hoe het gebaar zal worden gepresenteerd aan de ontvanger en de onmogelijkheid om bij het produceren van het gebaar te anticiperen op wat de ontvanger zal kunnen zien. De resultaten zijn gepresenteerd in een check-list met aanbevelingen voor de computerondersteuning van gebaren.

Samenvattend wordt er in het proefschrift een aantal aspecten van de user-interface ontwerpappraktijk behandeld. De ontwerpappraktijk blijkt zo divers te zijn dat het moeilijk is om ondersteuning te ontwikkelen die gebruikt kan worden door alle user interface ontwerpers. Tevens blijkt uit
het onderzoek dat de ondersteuning bij het ontwerpen van user interfaces met name verbeterd kan worden voor de volgende fases: het verzamelen van informatie over gebruikers en applicatiedomein, de samenwerking tussen leden van het ontwerpteam (o.a. de taakverdeling en het nemen van beslissingen), het maken van prototypes en de communicatie tussen mensen die betrokken zijn bij het proces. Vervolgens hebben we ons op het laatste aspect gericht. We hebben nader onderzocht hoe mensen in ontwerpgroepen gebaren gebruiken tijdens besprekingen. Uit het onderzoek blijkt dat de frequentie van de verschillende typen gebaren varieert met de taak. Daaruit volgt dat de mate en soort ondersteuning voor het maken van gebaren kan variëren per taak en daarvoor geoptimaliseerd kan worden. De studie heeft geresulteerd in aanbevelingen voor het ontwerpen van gebaarondersteunende hulpmiddelen.
Acknowledgements

I hereby would like to thank a number of people for contributing to my work. I would like to thank Rudy den Buurman for creating the opportunity and giving me the freedom to do such interesting research. I thank Kine Sittig for teaching me to ask questions, for inspiration and for trying to get the best out of me. Arnold Vermeeren has motivated me throughout the project. He has contributed a great deal to the work described in this thesis. I will not forget our many serious and less serious discussions. I very much enjoyed the pleasant and happy atmosphere in our room. I thank Judy Olson and Gary Olson for giving me the opportunity to do part of my research in their laboratory, and for their thorough and inspiring discussions. I want to thank Sjaak for his computer support, Sylvia for her statistical support, Frits for ideas on the lay-out and Angus for correcting my English writing. Last but not least, I thank all my other colleagues, but especially Mieke, Jozina, Paula, Guus, Gert-Jan, André and Brechtje for making work so much fun.