Referring in Multimodal Systems: The Importance of User Expertise and System Features

Daniela Petrelli
IRST - Istituto per la Ricerca Scientifica e Tecnologica
I-38050 Povo - Trento, Italy
petrelli@irst.itc.it

Antonella De Angeli **Walter Gerbino** **Giulia Cassano**
Cognitive Technology Lab. - Psychology Dept.- University of Trieste
Via dell'Università, 7 - 34123 Trieste - Italy
deangeli,gerbino,cassano@univ.trieste.it

Abstract

This paper empirically investigates how humans use reference in space when interacting with a multimodal system able to understand written natural language and pointing with the mouse.

We verified that user expertise plays an important role in the use of multimodal systems: experienced users performed 84% multimodal inputs while inexpert only 30%. Moreover experienced are able to efficiently use multimodality shortening the written input and transferring part of the reference meaning on the pointing.

Results showed also the importance of the system layout: when very short labels (one character) are available users strongly adopt a redundant reference strategy, i.e. they referred to the object in a linguistic way and use pointing too.

Starting from these facts some guidelines for future multimodal systems are suggested.

1 Introduction

Multimodal communication is used frequently and efficiently by humans to identify objects in physical space. By combining different modalities (e.g. speech and gestures), multimodal references act as efficient tools for coping with the complexity of the physical space -as conveyed by visual perception- which can be communicate only partially by verbal expressions (Glenberg and McDaniel, 1992). Therefore, multimodal references can easily substitute too complex, too detailed, ambiguous, or undetermined verbal expressions. In particular, they simplify referent identification when the speaker or the hearer do not know the name of the target, or how to describe it.

For a long time, face-to-face communication has been considered a reliable model for natural language based human-computer interaction (henceforth HCI) (Schmauks, 1987). Currently, little empirical work is available on what actually happens in multimodal HCI and how communication features cohabit with modern graphical interfaces (Oviatt, 1996; De Angeli et al., 1996; Oviatt et al., 1997; Siroux et al., 1995). Moreover, with only a few exceptions (Buxton, 1991; Brennan, 1991; Stock, 1995), direct manipulation interfaces have been seen as an antagonist of conversational interfaces, hindering a desirable synergy between the two communication styles.

We believe that in multimodal HCI users find strategies that overcome natural language communication or direct manipulation paradigm alone, creating a new mixed communication form that makes the best use of both (Oviatt, 1996; Oviatt et al., 1997). The new communication, even if similar in principle to face-to-face communication, might be carried out in a far different fashion because one partner is a computer. As a matter of fact, some studies showed that people do adopt conversational and social rules when interacting with computers (Nass et al., 1994) but humans also design their utterances with the special partner in mind (Brennan, 1991).

Empirical studies on natural language human-computer interaction confirm general HCI peculiarities. Talking to a computer humans maintain a conversational framework but tend to simplify the syntactic structure, to reduce utterances length, lexicon richness and use of pronouns (Jonsson and Dahlback, 1988; Dahlback and Jonsson, 1989; Oviatt, 1995). In other words users select a simplified register to interact with computers even if the (simulated) system has human capabilities (De Angeli, 1991).

These results suggest that face-to-face communication is not an adequate model for HCI. Therefore empirical studies are needed to develop predictive models of multimodal communication in HCI.

Empirical research becomes even more important when a multimodal system reproduces an *unnatural* modality combination, such as writing combined with pointing. Pointing while writing is highly different from pointing while speaking. In the first case, in fact, multimodal communication is hampered by a single-modality-production constraint. Indeed, the requirement of moving the dominant hand back and forth between the keyboard and a pointing device implies a substitution of the *natural* parallel synchronization pattern (Levelt et al., 1985) with an *unnatural* sequential one. Nevertheless, the obligation of using the same effector for writing and pointing does not seem to have any inhibitory effect on multimodal input production (De Angeli et al., 1996).

In general, deixis[1] was found to be the most frequent referent identification strategy adopted by users to indicate objects. However, its occurrence depends strongly on the effort needed to indicate the target by a pure verbal reference. Moreover, we found a relevant percentage of redundant references[2], a strategy mentioned in the relevant literature only for speech and pointing (Siroux et al., 1995) and pretty different from common face-to-face communication strategies (De Angeli et al., 1996).

Following the iterative design principles (Nielsen, 1993), we assume that experimental research, in the form of early simulations, should improve multimodal design by allowing to formulate reliable guidelines. From this point of view, the purpose of this paper is to investigate the effect of user expertise and system features on multimodal interaction in order to infer useful guidelines for future systems.

2 HCI issues in multimodal referring

In a HCI context where the user is required to write and point, we analyze the communication strategies that users spontaneously adopted at the very beginning of interaction. The main purpose of analyzing users' spontaneous behavior is to develop design guidelines that might be taken into account when developing multimodal systems that have to support successful interaction from the very beginning, like "walk-up-and-use" interfaces.

Results of a simulation experiment have been analyzed to answer the following question:

> **Is multimodal interaction really instinctive, i.e. do naive users perform as experienced ones?**

In general, multimodal systems appear to improve HCI by allowing humans to communicate in a more spontaneous way (Oviatt and Olsen, 1994; Oviatt, 1996). Therefore, one could infer that multimodal communication is the best interaction style for naive users. However, some authors suggest that language based interaction is mainly suitable for experienced users (Hutchins et al., 1986; Gentner and Nielsen, 1996). Indeed the opacity of language allows very flexible interaction, but requires previous knowledge[3]. We believe that experience, defined as computer science literacy, may increase the efficient use of multimodality. The notion of efficiency is defined, following (Mac Aogain and Reilly, 1990), as the capacity of the multimodal input to derive important semantic parts from information channels other than language, i.e. from pointing. In other words, efficiency is operationalized as the proportion of written input replaced by the gestural one.

3 Method

In order to evaluate spontaneous multimodal input production, data from the training session of a simulation experiment were analyzed.

Procedure The multimodal system called SIM, Sistema Interattivo per la Modulistica, was simulated to assist students with form filling tasks. Conversing with SIM, users had to gather information on how to fill out form fields (user questions) and to provide personal data for automatic insertion (user answers). Hard-copy instructions described system capability and required participants to complete the task as quickly and accurately as possible. No examples of dialogue were directly given, to avoid biasing communication behavior. Participants worked individually in a user room and were monitored by a closed circuit camera. Dialogues and pointing were logged and interactions videotaped during all experimental sessions. At the end all students filled in a user satisfaction questionnaire (USQ) and were debriefed.

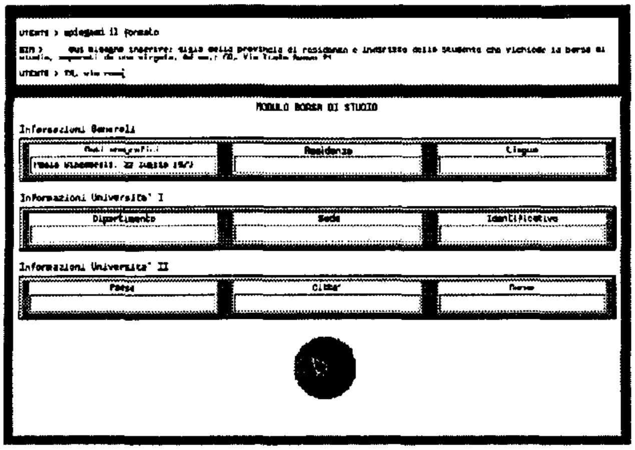
Simulation The system was simulated by the Wizard of Oz technique, in which a human (the wizard) plays the role of the computer behind the human-computer interface (Fraser and Gilbert, 1991). A semi-automatic procedure supported the simulation that was carried out on two connected SUN SPARC workstations. Interface constraints and several pre-loaded utterances (including a couple of prefixed answers for every task-relevant action, error messages, help and welcoming phrases) supported two trained wizards. These strategies have been found to increase simulation reliability by reducing response delays and lessening the attentional demand on the wizard (Oviatt et al., 1992).

The user interface was composed by a dialogue window in the upper part and a form window in the lower part of the screen (figure 1). In the dialogue

[1] Deixis concerns the ways in which languages encode or grammaticalize features of the context of utterance or speech event (Levinson, 1983). Among the various types we consider here only space or place deixis used in a gestural way.

[2] We defined *redundant reference* as multimodal references composed by a full linguistic reference and a not needed additional pointing.

[3] This is opposite to WYSIWYG (What You See Is What You Get) interfaces where what can be done is clearly visible.



UTENTE > spiegami il formato

SIM > Qui bisogna inserire: sigla della provincia di residenza e indirizzo dello studente che richiede la borsa di studio, separati da una virgola. Ad es.: TS, Via [illegible]

UTENTE > TS, via [illegible]

MODULO BORSA DI STUDIO

Informazioni Generali

Dati anagrafici	Residenza	Lingue
[illegible] 22 luglio 1972		

Informazioni Universita' I

Dipartimento	Sede	Identificativo

Informazioni Universita' II

Paese	Citta'	Corso

Figure 1: The user screen during an interaction.

window users typed their input and read system output. Pointing was supported by mouse and pointer was constrained inside the form window.

SIM was simulated with good dialogue capabilities, anyway still far away from human abilities. It accepted every type of multimodal references, i.e. with or without linguistic anchorage for the gesture and either close or far pointing. It could understand ellipses and complete linguistic references.

The form layout had nine fields grouped in three rows. Rows and fields had meaningful labels (one or two words) suggesting the required content. Users could refer both to single fields and to rows as a whole. At row selection SIM gave instruction on the whole row content. After users received row information, to further fields selection corresponded more synthetic instructions.

SIM required to click on the referred field and gave visual feedback to this[4]. It supported multiple references too. System answers were always multimodal with demonstrative pronouns and synchronized (visual) pointing.

Participants and Design Twenty five students from Trieste University participated in the simulations as paid volunteers. Ages of participants ranged from 20 to 31 and all were Italian native speakers.

Participants were grouped in two different sets according to their computer experience. Selection was achieved by a self-administered questionnaire on computer attitude and experience. Half sample was represented by experienced users, skilled typists with positive attitude towards computers and some programming experience. The other half was composed by students who had never used a computer before.

4 Results and Discussion

Data were available from 24 participants yielding a corpus of 210 user questions (due to technical problems one inexpert was discarded). User answers had to provide personal data for automatic insertion, but they did not require to identify fields. So user answers were not included in the analysis.

Each user question was tabulated in one of the following five categories according to the referent identification strategy adopted in it:

- **direct naming**: it is a unimodal reference and occurs when the field label is explicitly used in the utterance, e.g., *il campo dati anagrafici* (the personal data field);
- **language reference**: it is a unimodal reference and occurs whenever the field is referred by a pure verbal input, but without direct naming, e.g., *l'ultimo campo* (the last field). This category includes, among others, anaphoric reference and metonymia;
- **deixis**: it is a multimodal reference that occurs whenever an explicit anchor (deictic linguistic expression) for the pointing exists, e.g., *questo ↗ campo* (this ↗ field);
- **mixed**: it is a multimodal reference that occurs when the reference contains both linguistic and gestural part, but no deictic mark can be found in the utterance, e.g., *in ↗* (in ↗);
- **redundant**: it is a multimodal reference; it occurs when one component (or part of it) is not needed for the understanding, e.g., *il campo A ↗* (the field A ↗).

Figure 2 shows percentages of each referent identification strategies as a function of user expertise. It clearly emerges that previous knowledge affects strategy selection. Multimodal input were strongly preferred by expert users, while inexpert

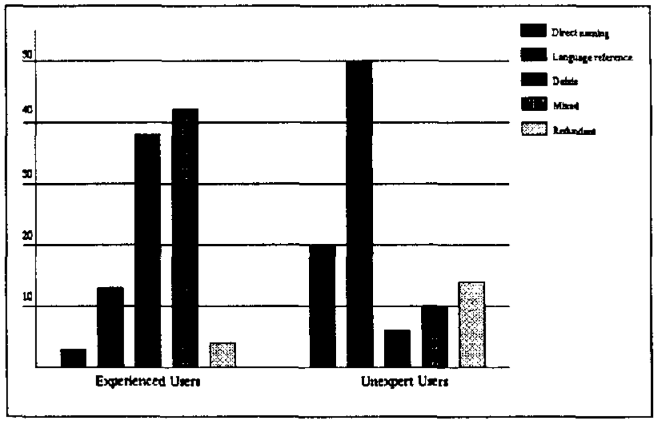
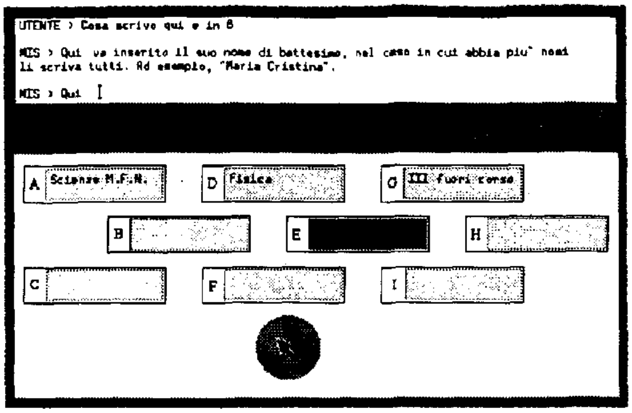


Figure 2: Referent identification strategies percentages as a factor of users expertise.

[4] In a previous study we demonstrated that visual feedback allows more efficient multimodal input, increases integration of pointing within writing and is preferred by users (De Angeli et al., 1996; De Angeli, 1997).



UTENTE > Cosa scrive qui e in B

MIS > Qui va inserito il suo nome di battesimo, nel caso in cui abbia piu' nomi li scriva tutti. Ad esempio, "Maria Cristina".

MIS > Qui

A Scienze M.F.N.

D Fisica

G III fuori corso

Figure 3: The MIS layout.

preferred unimodal linguistic references, especially direct naming[5]. These results imply that communication behavior may be predicted by knowing previous expertise.

Multimodal occurrence strongly increased efficiency of communication. Utterance length was found to be inverse correlated to the number of multimodal input (r=.48, p<.05). In average, expert users wrote almost 3 words each utterance, while inexpert nearly the double[6].

It is interesting to notice that, on the total sample, deixis and mixed input occur close to the same frequency. Mixed input implies a contraction of verbal input which is partially substituted by pointing, as in *cosa* ↗ (what ↗). This phenomenon is peculiar to HCI, and pretty infrequent in face to face communication where deixis (e.g. *cosa qui* ↗ - what here ↗-) represent the maximum efficient input.

Redundant input was pretty rare, with no significant difference due to expertise. This finding is in contrast with what we observed in (De Angeli et al., 1996). There, the simulated system, called MIS (Multimodal Intelligent System), had a quite different layout: each field had a very short label (a single letter) not related to the required content of the field (figure 3). With this layout redundant input was the 25% of the total.

We evince that the significant different rate when interacting with the two systems was due to form layouts. Indeed, redundant references in the case where labels were one character long was no-cost compared to the case where labels where one/two words long. This suggests that system layout may influence communication behavior. In the next chapter we discuss related guidelines.

When designing whatever system, specialists should consider both system functionalities and interaction features depending on the typology of users and on the tasks they will perform. In current multimodal systems, this balancing among functionalities and users has not been considered enough.

For example, the obligation for the user to point at a certain time while writing was found to be in contrast with his/her natural inclination. This constraint would be justified only if synchronization understanding is a true problem, e.g. if the users use multiple selection or pars-pro-toto. Our data show that, at least, this is not the case at the beginning of the interaction: expert used multiple selection in the 0.22% of the total multimodal references while for inexpert the percentage decrease furthermore to 0.14%.

5 Lessons Learned and Proposed Guidelines

In this section we state some guidelines useful for designers of walk-up-and-use multimodal systems or for systems that have to have a successful interaction from the very beginning.

As widely discussed above, user expertise is a factor that deeply influences multimodal interaction. In our experiments, experienced users took advantage of multimodality in the 84% of all the considered interactions. At the opposite, multimodality was not exploited by the inexpert that used it only for 30%. These data indicate that multimodal systems are definitely suited for expert users even from the very beginning of the interaction, while inexperts have difficulties in exploiting multimodality interaction limiting themselves to inefficient linguistic references.

To help a naive user to overcome this initial gap, it may be useful to plan some mechanisms, such as contextual help or specific tutoring answers, aiming at directing linguistic references toward multimodal ones. This strategy could be especially important in systems, like tourist kiosks, where the user might have difficulties in stating the name correctly.

Another interesting point is that experienced users perform nearly the same percentage of deixis (38%) and of mixed modality (42%). This suggests that systems should be flexible enough to accept whatever combination of pointing and writing, not requiring a well formed deixis.

An important guideline is therefore to not require a prefixed behavior from the user, to say to not pretend well formed deixis or the pointing in a specific position. We claim that flexibility has to be preferred to more sophisticated system facilities, such as multiple pointing, since users do not make the most of them.

[5] According to the results of a Mann-Whitney U test the ratio of multimodal input to total questions in the two experience groups is statistically significant, U = 10,5, (N=23) p<.001 .

[6] The difference is significant according to results of an ANOVA F(1,22) = 12.21 p<.001 .

The flexibility concept is strengthened by the fact that users can find very efficient ways for referring, optimizing writing and pointing and exploiting the context as in "↗?" where the meaning is conveyed by the gesture, by the minimal writing and by considering the task the user is performing.

Consequently, a further step toward a flexible system would be to use all the possible information sources to interpret user multimodal input, to say not only linguistic and gestural input but also discourse history and task model.

Lastly, the influence of the layout on the user behavior has to be underlined. In fact, the possibility of referring to objects in a no-cost linguistic way (e.g. a single character) encourages the user to use redundant references. This suggests to design the interface using very short labels whenever a double reference is useful to discriminate objects, for example on dense maps.

More in general, we verified that conclusive results coming from related fields can not be simply transferred to the multimodal domain. This is the case of models from human-human communication that do not exhaustively describe all phenomena occurring in multimodal human-computer interaction. For example, we showed that mixed inputs like *cosa* ↗ (what ↗) are pretty frequent whereas they are hardly used in face to face dialogues. Similarly, Gestalt guidelines for graphical interface design may not have the expected effect on users behavior in complex multimodal referring. For example, even thought rows of objects are clearly displayed (a frame around homogeneous objects let the user perceive a single set), users seldom refer to rows (e.g. by their title or by clicking the row background) preferring repeated references to each object.

Building on our experience, we believe that, even if some work has been already done, empirical investigations are still needed to complete the picture of human-computer multimodal interaction.

Acknowledgments

This research was partially supported by the CNR Grant for the project "An ecological approach to the implementation and evolution of multimodal systems".

References

Susan Brennan. 1991. Conversation as direct manipulation: An iconoclastic view. In Brenda Laurel, editor, *The Art of Human-Computer Interface Design*, pages 393–404. Addison-Wesley.

Bill Buxton. 1991. The "natural" language of interaction: A perspective on nonverbal dialogues. In Brenda Laurel, editor, *The Art of Human-Computer Interface Design*, pages 405–416. Addison-Wesley.

Nils Dahlback and Arne Jonsson. 1989. Empirical studies of discourse representations for natural language interfaces. In *4th European Conference of ACL*, pages 291–298.

Antonella De Angeli, Daniela Petrelli, and Walter Gerbino. 1996. Interface features affecting deixis production: A simulation study. In *WIGLS - Workshop on the Integration of Gesture in Language and Speech (at ICSLP'96)*, pages 195–204.

Antonella De Angeli. 1991. Dillo a MAIA. Master's thesis, Psychology Dept.- University of Trieste.

Antonella De Angeli. 1997. *Valutare i sistemi flessibili: un approccio globale alla HCI.* Ph.D. thesis, University of Trieste.

N. Fraser and G. Gilbert. 1991. Simulating speech systems. *Computer Speech and Language*, pages 81–99.

Don Gentner and Jakob Nielsen. 1996. The anti-mac interface. *Communication of the ACM*, 39(8):70–82.

A. Glenberg and M. McDaniel. 1992. Mental models, pictures, and text: Integration of spatial and verbal information. *Memory and Cognition*, 20(5):458–460.

Edwin L. Hutchins, James D. Hollan, and Donald A. Norman. 1986. Direct manipulation interfaces. In Donald A. Norman and Stephen W. Draper, editors, *User Centered System Design: new Perspectives on Human-Computer Interaction*, chapter 5, pages 87–124. Lawrance Erlbaum Associates.

Arne Jonsson and Nils Dahlback. 1988. Talking to a computer is not like talking to your best friend. In *Scandinavian Conference on Artificial Intelligence- SCAI'88*, pages 53–68.

Willem Levelt, Graham Richardson, and Wido La Heij. 1985. Pointing and voicing in deictic expressions. *Journal of Memory and Language*, 24:133–164.

Stephan Levinson. 1983. *Pragmatics.* Cambridge Textbook in Linguistics. Cambridge University Press.

Eoghan Mac Aogain and Ronan Reilly. 1990. Discourse theory and interface design: The case of pointing with the mouse. *International Journal of Man-Machine Studies*, 32:591–602.

Clifford Nass, Jonathan Steuer, and Ellen Tauber. 1994. Computers are social actors. In *CHI'94 Human Factors in Computing Systems*, pages 72–78. ACM Press.

Jakob Nielsen. 1993. *Usability Engineering.* Academic Press.

Sharon Oviatt and Eric Olsen. 1994. Integration themes in multimodal human-computer interaction. In *International Conference on Spoken Language Processing*, pages 551–554.

Sharon Oviatt, Philip Cohen, M. Fong, and M. Frank. 1992. A rapid semiautomatic simulation technique for investigating interactive speech and hand writing. In *International Conference on Spoken Language Processing*, pages 1351–1354.

Sharon Oviatt, Antonella De Angeli, and Karen Kuhn. 1997. Integration and synchronization of input modes during multimodal human-computer interaction. In *CHI'97 - Human Factors on Computing Systems*. ACM Press.

Sharon Oviatt. 1995. Predicting spoken disfluences during human-computer interaction. *Computer Speech and Language*, 9:19–35.

Sharon Oviatt. 1996. Multimodal interfaces for dynamic interactive maps. In *CHI'96 - Human Factors in Computing Systems*. ACM Press.

Dagmar Schmauks. 1987. Natural and simulated pointing: An interdisciplinary survey. Technical report, FB Informatik, Universität Saarbrücken.

Jacques Siroux, M. Guyomard, F. Multon, and C. Remondeau. 1995. Oral and gestural activities of the users in the georal system. In H. Bunt, R. Beun, and T. Borghuis, editors, *International Conference on Cooperative Multimodal Communication (CMC'95)*, volume 2, pages 287–298, May.

Oliviero Stock. 1995. A third modality? *Artificial Intelligence Review*, 9:129–146.