Interacting with Navigation Devices: A Case Study

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***Abstract*— The paper aims to study the adequacy of interactive capabilities in commercial navigation devices. In order to do this, an experiment is proposed and two sets of results are obtained and analyzed: one resulting from the application of objective metrics; and the other one, from subjective answers of the device users when queried about their experience. To the extent that these interactive capabilities are found to be inadequate, it is the goal of this study to ascertain (1) whether a more natural, human-like interaction paradigm (i.e., natural interaction) ought to be incorporated into these kinds of devices and, if so, (2) the extent to which their interactive capabilities improve as a result. For this, a direct comparison of device interactive capabilities with those of human beings is necessary. Study results suggest that the incorporation of natural interaction in navigation devices may help respond to certain device interactive inadequacies as well as to the user dissatisfaction which those inadequacies engender.**

Keywords- Guiding Service; Natural Interaction; Evaluation

I. INTRODUCTION

Among the important challenges in the technological field today is that of the selection of the most suitable mechanisms by which particular devices interact with. It is broadly accepted that, for a given device, the most suitable interface is not necessarily the most complex one. Some interfaces have been used over many years and thus enjoy a high level of user familiarity (e.g., it is hard to imagine how to improve traffic lights for the sharing of a crossroads). In fact, for most devices, the simplest interface is often thought to be the best. For this reason, current trends point to minimalist interfaces [13], even for complex devices. Given particular contextual information, then, these devices should be able to find the right command. However, their use is not necessarily simple and may require including additional interfaces, leaving the minimalist interface as a shortcut.

With users specifically in mind, intuitive interfaces are often sought out that are icon-based and supported by touch screens. However, as discussed in other studies [5], the ultimate user-oriented goal is achieving a system which behaves in a more human-like way and, more specifically, interacts with users in the same way that those users might do with other human beings. For this reason, voice technologies are applied to many systems – since they are more familiar and accessible for most users – and often complemented with a graphical user interface (GUI). Additionally, several systems have also been developed to emulate other aspects of human interaction such as dialogue strategies, turn-taking, adaptation to the interlocutor and contextual awareness.

The present paper explores the suitableness of this sort of interaction paradigm in navigation devices. Since the tasks for which these devices are created are also regularly performed collaboratively by human beings, one may think that the application of the NI paradigm should be highly beneficial. Not surprisingly, then, recent years have seen the development of prototypes of multimodal interaction systems for guiding by several research groups in the field [10][15]. However, before such costly research is undertaken, it is advisable first to conclusively determine (1) whether the NI paradigm is, in fact, suitable for incorporation in navigation devices and (2) whether current navigation devices already possess sufficiently adequate interactive capabilities (i.e., without the incorporation of the NI paradigm).

In the present case study, the interactive capabilities of a commercial device for pedestrian navigation supported by GPS are studied. In order to observe the results obtained through the incorporation of the NI paradigm in the device, a human tester is used to simulate the role of a more human-like interface, while not interfering with the tasks performed.

Finally, it is important to remember that collaborative task performance does not necessarily mean that participants are exclusively committed to its execution. Quite to the contrary, participants often juggle several concurrent goals– some shared and others individual. With this fact in mind and in order to ensure the realism in the experiments, both participants are assigned a second, background collaborative task to be performed simultaneously with the first.

II. RELATED WORK ON HUMAN-LIKE INTERACTION

Primarily for the purpose of achieving greater accessibility, NI research seeks to endow systems with more natural interactive capabilities. In this way, users with relatively little to no technological training are able to access information, applications and services provided by the system [5]. Furthermore, this sort of interaction offers a convenient and appealing alternative for more technologically literate individuals, as well, particularly when traditional modes of interaction become cumbersome.

One of the principal features of human interaction is its flexibility with regard to both the conceptualization and expression of utterances. Human interlocutors exploit a wide range of lexical and expressional resources and dialogue strategies at their disposal. For quick adaptation to changes in the interaction, particular resources and strategies utilized by the interlocutor may be substituted for others at any moment. The reasons for this interactive behavior can be understood according to Grice's conversational Maxims [8]:

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be sufficiently but not excessively informative (Maxim of Quantity), be truthful (Maxim of Quality), be relevant (Maxim of Relation) and be clear (Maxim of Manner). These Maxims have already been used by Harris [9] to support the evaluation of voice systems.

It is important to emphasize, however, the fluid and overarching quality of the Gricean Maxims. In order to obtain a particular (and often non-literal) conversational result, for instance, Maxims may be consciously flouted by an interlocutor [3], essentially converting the Maxims into extensions of the dialogue strategies in the interlocutor's arsenal. Additionally, interaction and its interpretation according to the Gricean Maxims in a particular case, is framed by different contextual aspects which may be classified as material (i.e., time, place, weather ...), semiotic, political, operative and socio-cultural environment [7].

Other important elements frequent in human interaction are interruptions [1]. Individuals are almost always in the process of performing tasks to achieve specific goals. While they may collaborate in the execution of a shared task, it is most often the case that those task participants are also simultaneously involved in the execution of several other tasks. When a particular individual needs to communicate information, this act will almost always result in the interruption of another task being executed by the receiver [12]. Even after the participants begin interacting, an utterance by one of them to the other may nevertheless be considered an interruption if either the former or latter participant happened, at the same time, to be in the middle of a different utterance (i.e., *self-interruptions and locutive interruptions*, respectively), to be talking about a different topic (i.e., *dialogue line interruption*) or to be using a different dialogue strategy (i.e., *development interruption*). A participant desiring make such an interruption decides to act or to refrain from acting on this desire based on an analysis of the costs and benefits resulting from the interruption [11][14]. However, those costs may nevertheless be reduced either through the employment of certain interaction techniques, such as pre-sequencing and displays of awareness [6], or by choosing the proper moment [2].

To endow a system with these interactive capabilities and characteristics, NI research seeks to gather knowledge about human interaction and reasoning mechanisms. A main trend in NI research is the classification and distribution of knowledge involved in the human interaction process across specialized models. Among some of the different types of models proposed in a previous study [4], interaction structures and intentions would be handled by a dialogue model, turn-taking by a presentation model, interlocutor characterization by a user model and context management by a situation model. Other frequently included components are the emotional models, task models, system (or self) models, ontology and, of course, interface components. Each particular knowledge distribution depicts an NI cognitive architecture, several examples of which being found in the literature [16]. These models are often implemented by autonomous agents [5] continuously processing the interaction and cooperating to achieve the global goal of a more natural human-like interaction.

III. CASE STUDY EXPERIMENTS

For the sake of clarity, the section is divided into five sub-sections detailing the design, preparation and results of the experiments. The discussion can be found in Section 4.

A. *Experiment Design*

The experiments conducted for this article studied the interaction between two individuals playing the roles of user and guide, where the former is the test subject and the latter the experiment leader. In addition to the latter's role as guide, the experiment leader was also responsible for recording the interactions with the test subject, the breaks taken between experiments and the later interview of the test subject following the completion of the experiments. In addition to these two participants, a third participant shadowed the former two as an objective observer, manually noting down any important events that arose during the dialogue without ever directly intervening in the interaction itself. This observer was also responsible for conducting the post-experimental interview of the test subject.

The interaction studied in these experiments was developed around the simultaneous execution of two distinct, high-level tasks: (1) a principal task of guiding a user along a route from a fixed start point to a fixed end point and (2) a background task of exchanging information (i.e., chatting) about a set of films proposed by the test subject. The background task was incorporated into the experiments in order to produce real human interactions in which participants are often engaged in the simultaneous execution of multiple tasks. Furthermore, the specific topic of this background task was chosen due to its emotionally-engaging nature, thereby commanding higher interactive commitment from the user [4]. Consequently, the importance given by the user to the main task, while still high, would nevertheless not be absolute and any unnecessary use of resources in its development, therefore, would detract from the development of the emotionally-engaging background task and most likely annoy the user. Finally, walking routes are preferred since they reduce risks and make easier to observe the test subject. Besides, and insofar as the experiments took place in a real environment requiring participant attention (e.g., awareness of road conditions to avoid being hit by a car), a third, low-level task of environmental awareness was also considered.

Consistent with what has been discussed in previous sections of the article, the main goal of these experiments was to observe the oral interactions produced by navigation devices (GPS) and to contrast them with human interactions produced in the same operational context. The experiments were supported by a GPS device chosen from among the most popular, commercially available models. It was carried by the experiment leader who hid GPS visual displays while ensuring that audio utterances were perfectly audible for the user. The leader was allowed to provide additional information for the development of the main, high-level task, but only if absolutely necessary and strictly limited to verbal utterances (i.e., avoiding spatial deixis through gestures).

Since events occurring in the test environment during the execution of the principal high-level task and the low-level task were likely to grab the participants' attention, several

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different navigation routes were developed and executed in the experiments by each test subject. The specific routes were designed for the experiments to reflect different levels of navigational difficulty through varied route lengths, numbers of hotspots (i.e., points where the user is more likely to get lost) and environmental elements (i.e., elements requiring different levels of attention to the low-level task).

The routes were set prior to the execution of the experiments and were the same for all test subjects. Three routes were developed: one comprised entirely of roads, another comprised entirely of walkways and the third comprised of both roads and walkways. The routes were located to be executed in succession while, at the same time, allowing for a short break in a quiet area between each task. The routes were designed to take an hour to cover them all (including breaks). The test subjects were screened prior to the experiments to ensure that none was familiar with the destinations of the different routes or even the majority of roads or walkways traversed in order to reach those destinations. The experiment crew formed by the experiment leader and observer received training on the routes to be followed prior to the execution of the experiments.

B. *Participant Selection and Experiment Preparation*

In a preparatory phase of the experiments, the specific GPS device to be used, the routes to be followed and the test subjects to participate as users in the study were all preselected. For the selection of the device, a Garmin nüvi® navigator was chosen due to its wide commercial use and popularity. The three routes for the experiments were developed in the Spanish city of Leganés due its proximity to Madrid and fulfillment of the environmental requirements discussed earlier. The total length of the routes developed was less than 3 kilometers with an estimated total completion time – including breaks and travel times between routes – of less than one hour. Nevertheless, it was understood that actual route lengths and estimated completion times would likely vary from subject to subject, particularly in the case that a test subject misunderstood the instructions or selected a path different from that given by the navigator. Specific details about these routes (i.e., road, walkway and hybrid routes) are presented below in TABLE I.

TABLE I. DESCRIPTION OF ROUTES DEVELOPED

Route	***Roads (#)***	***Walkways (#)***	***Hotspots (#)***	***Length (m)***	***Time (min)***
Hybrid	6	3	5	1100	20
Roads	4	-	7	850	14
Walkways	-	3	4	500	7

As noted by the observer, road routes in the experiments appeared easier for navigation than others due to the restricted space for pedestrian transit and the fewer points along the route (i.e., hotspots) requiring a navigational decision by the test subject. However, the traffic likely to be present in the test environment would nevertheless pose greater dangers for the test subject, therefore requiring a greater dedication of interaction resources to the execution of the low-level task (i.e., environmental awareness).

Regarding the selection of test subjects, 50 candidates were interviewed with the aim of obtaining a wide distribution of primary characteristics – such as age and experience with GPS devices – and secondary characteristics – such as personal sense of direction, experience with computers and experience with technological devices, in general. Of the candidates interviewed, 22 were selected in such a way as to maximize these distributions of primary and secondary characteristics, thereby producing more generalizable results. In order to reduce any potential effects of the route sequencing, all selected test subjects were given a training session prior to the experiments which included a description of the process and a brief trial run.

C. *Data Acquisition*

Experiments in this study were organized such that the data recorded would allow researchers to observe to what extent Gricean Maxims (see Section II) were met in the interaction between the GPS device and test subjects. While all Gricean Maxims were considered, less importance was given here to the Maxim of Quality insofar as a lack of "truthfulness" would not reflect the interaction quality, but rather the positioning technology precision, which is not the focus of the present study. Observations regarding temporal realization and interruptions were of particular interest, since both of them are characteristic of human-like interaction, yet frequently overlooked by classical interaction systems.

In order to allow for the natural execution of tasks, it was deemed most appropriate here to employ a procedure of external observation followed by the subsequent collection of test subject impressions regarding the interaction and the experiments themselves. According to this procedure, the observer noted all important details and events in each case with specific attention paid to the details discussed below.

Regarding the Gricean Maxim of Quantity, any moments where the device provided the user with either insufficient or excessive navigational information were to be noted down by the observer. They were respectively measured as user utterances made to request omitted information and useless interventions, both regarding total number of utterances.

Nevertheless, as redundancy is not necessarily a negative indicator, but may, in fact, be required in certain cases, redundant device utterances were noted down by the observer, classified as either useful or superfluous and later analyzed. Where a device utterance was considered to be superfluous, the observer was also to detail the user's reaction to the utterance, noting if the user responded with any signs of annoyance. Besides, as relevant information may nevertheless fail to fully produce its desired effect if not framed in the proper manner, the experiment observer was charged with recording the number of times a user requested clarification, hesitated or made an incorrect decision.

All these observations were presented together according to the routes during which they were originally recorded. Since each route is of a different length and possesses a different number of hotspots, the effective comparison of results recorded requires a prior normalization of the data. For this normalization, the average execution time and number of decisions point for each route was calculated.

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Apart from the details described above, the observer was instructed to record any comment or gesture made by the test subject during routes. Through breaks no notes were taken, for the test subject to feel less scrutinized and more willing to talk freely about the interaction experience. Comments made by the test subject during pauses were transcribed from the recordings following the completion of the experiments.

In order to complete the subjective data obtained during the experiments, then, open interviews of test subjects were conducted (following the completion of the experiments) in which the interviewer (i.e., the observer) focused on five topics of specific relevance to the aims of the study: (1) the quantity of information provided, (2) the usefulness of the information provided, (3) the clarity of device utterances, (4) the timing of the utterances, and (5) the subjects' preference to interact with a human being or a device in the execution of navigational tasks. Just as occurred during the pauses between routes and in order to ensure a relaxed interview environment and lively test subject responses, no manual notes were taken during the interview. Instead, questions and responses were recorded electronically and later transcribed.

D. *Objective Results from Observation*

Following the completion of the experiments, the data collected by the observer was prepared for analysis. Most interesting results recorded are presented in the following graphs. In Figure 1.a, the number of regular, redundant and clarificatory device utterances per hour is shown. The data is presented both for each specific route studied as well as for the experiments as a whole (i.e., the totality of the routes).

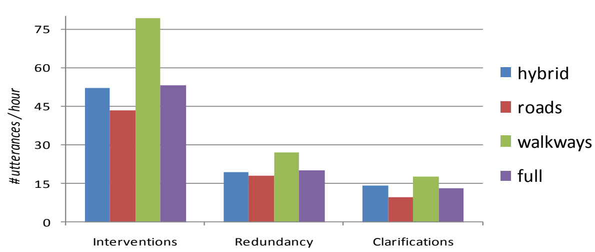

Figure 1.a: System utterances per hour

Figure 1.b presents the number of regular, redundant and clarificatory device utterances made per navigational decision point. The organization of the data, however, is the same as in Figure 1.a. From the data presented, road routes appear to require less interaction resources than the other types of routes studied. This corroborates the observer statements discussed in sub-section B. in which road routes were said to be slightly easier than the others.

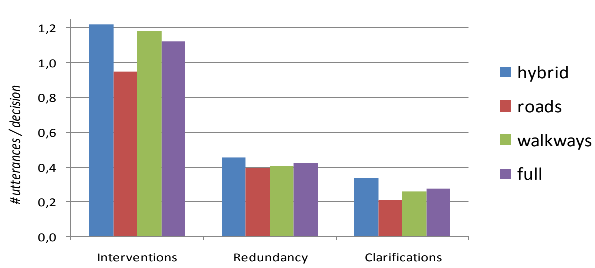

Figure 1.b: System utterances per decision

In the former figure, a large number of redundant utterances can be observed, jeopardizing the likelihood of a favorable analysis of the device with regard to the Maxim of Quantity. The significant number of clarification requests also corroborates this last point with regard to the Maxim of Quantity. Figure 2.a and Figure 2.b below offer this additional analysis by classifying the redundancies produced.

As clearly visible in Figure 2.a, one out of every seven device utterances provided no new information or useful redundancies and, therefore, could have been avoided. Furthermore, almost half of the superfluous utterances were considered annoying by test subjects. As a result, it can be concluded that the navigational device's interactive capabilities do not conform to Grice's Maxim of Quantity.

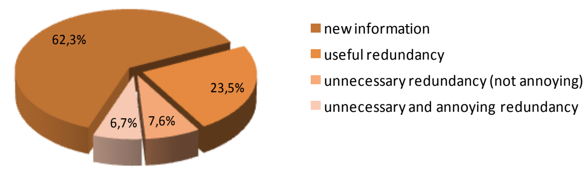

Figure 2.a: Classification of redundancies (% totals)

While of relatively lesser importance, it is nevertheless interesting to note here that Figure 2.b shows that unnecessary and annoying redundancy during walkway routes is greater than unnecessary not annoying redundancy. Therefore, redundancy is more likely to annoy users in walkways. This finding is at odds with the earlier difficulty assessment made by the experiment observer, according to which road routes were said to be easier.

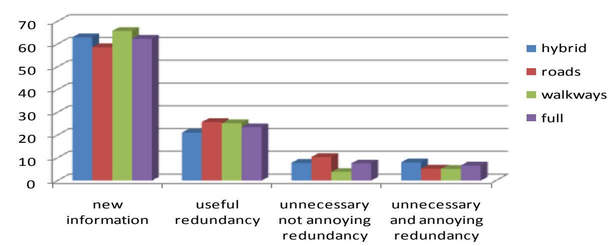

Figure 2.b: Classification of redundancies (% per route)

Regarding the timing of device utterances, Figure 3.a reveals that 16.7% of all utterances were considered ill-timed by users, suggesting a relatively low degree of informational relevancy in these cases. Although the contents of device utterances are, strictly speaking, limited to information relevant to the navigational task, the untimeliness and exaggerated redundancy of utterances may lead one to conclude that the interactive capabilities of the navigation device do not satisfy Grice's Maxim of Relation, either.

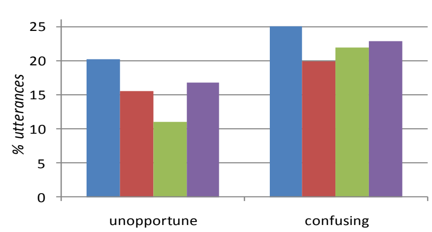

Figure 3.a: Percent of utterances considered ill-timed or confusing

Furthermore, untimely utterances may also endanger the success of the interaction. Figure 3.a shows that users found 23% of all device utterances confusing. With such a high percentage of imprecise or confusing utterances, clearly the Maxim of Manner is not satisfied by the interactive capacities of the navigational device, either. As illustrated in Figure 3.b, untimely and confusing utterances account jointly for the fact that users hesitated in 14% of all decisions made and that 7.7% of all decisions made were incorrect.

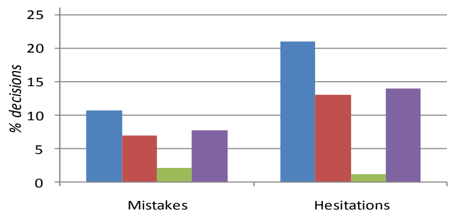

Figure 3.b: Percent of user decisions with mistakes or hesitations

Finally, the graphs demonstrate that walkway routes involve fewer user mistakes and hesitations despite similarly elevated percentages of ill-timed and confusing utterances. Similarly, almost all users appeared to the observer to be more relaxed and self-confident in walkway routes than in other routes. While these results may seem strange given the walkway routes' greater relative difficulty, they can nevertheless be explained by taking into account (1) the higher number of user requests for clarification (see Figures 1.a and 1.b) and (2) the greater insignificance of the environment events (i.e., the low-level task) present in the walkway routes. Consequently and to revise an earlier conclusion, it appears that car traffic in the environment does in fact affect test subjects who utter fewer requests for clarification despite harboring greater doubts regarding the correctness of their navigational decisions. Regarding the hybrid route, users appeared to have problems particularly when moving from a pedestrian walkway to a road. This is understandable when one considers the fact that while continuous, contextual changes affect the user significantly, the non-human-like navigation device is incapable of adapting its interactions to these contextual shifts.

E. *Subjective Results*

The subjective opinions of test subjects regarding their interactions with the navigation devices were gathered in open interviews following the execution of the different route tasks and later analyzed by the researchers. The results obtained are presented below in Figures 4.a to 4.d.

Figure 4.a illustrates that all test subjects thought that the device should have provided more information on at least some occasions, yet very few subjects found a lack of information in device utterances to be the norm. Figure 4.b shows that most users considered that the system produced more utterances than were necessary. While only a third of users characterized the interaction as not redundant, the remaining users believed the interaction to have been unnecessarily redundant, with almost half of whom considering the redundancies to be annoying to the point of jeopardizing the success and tolerability of the interaction.

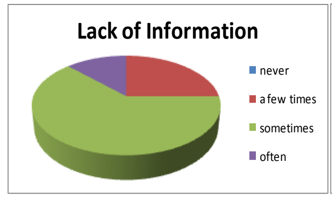

Figure 4.a: How often was information lacking?

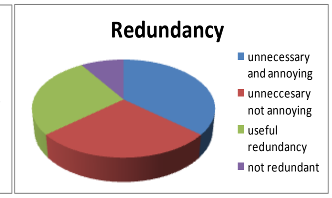

Figure 4.b: Was the interaction redundant?

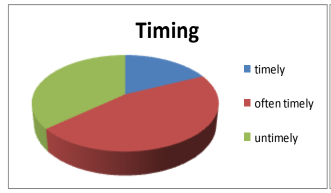

Figure 4.c: Was the information in a timely manner?

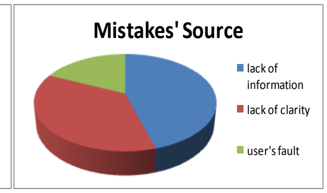

Figure 4.d: What caused provided in the mistakes?

Relevancy, on the other hand, can be examined from Figures 4.b and 4.c. User opinions regarding the usefulness of device utterances are particularly low. Not only were interactions viewed as unnecessarily redundant, but most users also believed the devices to have provided ill-timed information (i.e., either too early or too late), with more than a third of whom having believed this untimeliness to be the norm for the devices. It is clear yet again that the interactive capabilities of the devices do not meet the Maxim of Relation.

Regarding manner, 45% of users considered device utterances confusing. However and as shown in Figure 4.d, when asked about the causes of those errors in the navigation process, nearly the same, large percentage of users believed the errors to have been caused either by a lack of clarity or by a lack of information.

Finally, when confronted directly on the question of preference between a human guide or navigation device, the vast majority of test subjects stated a preference for the human guide, with only 9% of subjects stating a preference for the navigation device. Among this 9% of subjects preferring the navigation device, the majority were highly technologically trained individuals who either (1) enjoyed daily experience with similar devices or (2) possessed an engineering degree and spent over 10 hours per day with computers. When asked about the reasons for their expressed preference, over 70% of users mentioned that human beings are more precise and can adapt their utterances to the circumstances of the interaction. Users preferring navigation devices tended to focus on their availability and speed..

IV. Discussion

From the objective results presented in the previous section, it is clear that the Gricean Maxims of Quantity and Relation are not met by the interactions of the navigation device. The interaction, however, may still be considered good enough insofar as only one device utterance out of every seven was of no use and less than half of these useless utterances annoyed users. Nevertheless, the interactions lead to frequent user hesitation (in approximately 14% of user decisions made) and multiple user errors (in 8% of user decisions made). This last fact is likely due to the lack of

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timely and precise device utterances (one out of every six device utterances was ill-timed and nearly one out of every four device utterances was confusing in some way) revealing the inadequacy of device utterances in meeting the Maxim of Manner. It must be noted that while navigation device interactions may be correctly and satisfactorily developed under optimal conditions, real circumstances are rarely if ever optimal. Thus, it may be concluded that the Gricean Maxims are rarely if ever met by these devices' interactions.

Despite these conclusions, however, defenders of navigation devices might argue that any mistake made may be quickly addressed and corrected by the device through the recalculation of a new route. Furthermore, human interaction is far from perfect, either. While this may be true, however, the impact of the interaction on other concurrently executed tasks is definitive. Additionally, comments recorded during breaks from route executions revealed some novice users to have held unrealistically high expectations for the navigation device and other users to have been prejudiced against technology. Finally, while test subjects knew nothing about the ultimate goal of the experiments – the evaluation of the interactive capabilities of navigation devices – they nevertheless sensed that navigation device technology was being closely examined. As a result and given particular user profiles, some users may have been inclined to more vehemently defend the devices than they would have done otherwise, while other users may have done just the opposite.

V. Conclusions and Areas for Future Research

This study has aimed to assess the quality of interactions developed by current navigation devices and to see whether other interactive paradigms could be considered for them. Although some features of human interaction, such as audio channel, have been incorporated into the devices, they are still quite mechanical and primitive compared with fully-human interaction. Among the principal weaknesses of these devices is their inability to adapt to circumstances involving the interlocutor or the interaction itself. This lack of adaptability leads to errors in the quantity of information provided, as well as in the timeliness and manner of the utterances produced. These shortcomings can be overcome through the inclusion of a natural, human-like NI paradigm.

Notice, however, that while this is clearly the case, NI research is not yet mature enough to completely address this necessity. Besides, improvements could still be included in navigation devices as new advances in NI research are made. These gradual, small upgrades should be made while, at the same time, attempting to avoid conflicts resulting from excessively high user expectations. In any case, even if the NI upgrades were complete, the devices would still not likely achieve perfect marks from users. Expert human guides do not generally receive perfect user marks, either.

Concerning the methodology used in the experiments of the present study, it seems adequate for obtaining useful information on the weaknesses of current navigation technologies. Gricean Maxims also proved a good point of reference for the comparison of human and non-human interaction paradigms. However, as interactive capabilities of devices continue to evolve and include more and more human-like interactive strategies (e.g., flouting the Gricean Maxims), a more sophisticated theoretical background will be necessary for their complete assessment. For this reason, it would be particularly advantageous for future assessments to develop a tailored evaluation methodology for NI systems.

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