The Effect of System Usability and Multitasking Activities in Distance Learning

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ABSTRACT
In this paper we describe a study in which we assessed the effects of the usability of a teaching system designed for distance learning in the context of different types of multitasking activities. The learning performance of six groups of students has been compared after their individual interaction with a system that was either usable or not, and in conditions of simple learning, sequential multitasking or concurrent multitasking. Results show that learning processes are negatively affected by the use of a system that is difficult to use. In addition, learning in multitasking conditions appears to be a difficult task only when students have to acquire new information while doing something else at the same time (concurrent multitasking). The usability levels of the system do not seem to interact with the multitasking modality of learning.

Categories and Subject Descriptors
K.3.1 [Computer and Education]: Computer Uses in Education – distance education.

General Terms
Performance, Design, Human Factors.

Keywords
Distance education, user interface, usability, multitasking.

1. INTRODUCTION
Quite recently, several studies have tried to investigate whether and how learning processes can be affected by the level of usability of training systems designed for distance learning. However, the exploration of this issue did not prove to be an easy task. A first important difficulty, in relation to this goal, may be ascribed to the way in which usability is evaluated. Research in this field by far has developed several methods and techniques to efficiently evaluate the usability of a system, many of them based on expert evaluation [1; 2; 3], while others on empirical studies [4] and also on the combination of different methods [5; 6; 7; 8]. By adopting these analytical and implementative methods, it has been possible to produce valuable knowledge, sometimes at a very fine-grained level, about the way in which the usability of different teaching systems is likely to interact with other variables, such as the level of technological sophistication [9], the possible cooperative usage of the same system [10], the adoption of e-learning applications in blended training courses [11].

Many questions, however, are still open. For instance, a number of studies showed that many systems for distance learning exhibit higher dropout rates than traditional courses, namely those based on face-to-face interaction [12; 13]. Moreover, some perplexities are being increasingly advanced about the actual level of usability of many training systems, and about how to evaluate it. Learners are increasingly diverse, learning tasks are continuously redesigned and technological advances are very difficult to foresee. All these variables, combined together, make it very difficult to define the actual usage context of e-learning applications.

Further knowledge is thus needed about the effectiveness of these systems when they are used in conditions in which learners are not directly supervised, and when they are involved in learning processes through the interaction with the training system in their own environments, whether at home or in an office. In these circumstances, it becomes very hard to predict how the system will be actually used, how many people will together use it, and with what pace and under what cognitive and operational workload. Most notably, during the design and the implementation of training systems, the relevance of workload, due to the activity of the learner himself or generated by the environment, is a factor usually underestimated. This in spite of the fact that nowadays, due to the pervasiveness of ICTs, we are all continuously requested to process an infinity of stimuli, and to respond to an increasing number of operational demands, which require us to behave as effective multitaskers.

Multitasking is a phenomenon that has been defined in different ways, and it is hard to deal with it without being influenced by the suggestions, either extremely positive or dramatically negative, that mass media have debated with increasing frequency during last years.

Actually, multitasking can be seen as one of those expressions of human behavior that best exemplify the high level of sophistication of our cognitive processes. We are in fact able to do a lot of things at the same time and, doing so, we show surprising adaptive behaviors.

However, regardless of the relevance of these questions, by far the way in which being involved in multitasking activities may affect learning processes, and how different levels of usability of the systems could affect the execution of multitasking activities have not yet been sufficiently analyzed. This may be related to the fact...
that multitasking is neither a well-defined phenomenon, nor one that can be univocally described. Multitasking, in fact, may occur in many different ways, and its consequences on the tasks under execution may also be very different depending on the ways in which the activity is performed.

As maintained by Salvucci [14] different variables can be used to characterize multitasking. At a macroscopic level, the characteristic of the tasks, whether they are continuous or discrete, should at least be considered. Continuous tasks are those tasks that may be executed even without a precise definition of the goals to be attained, and without involving action schemata and feedback modalities of action control. Discrete tasks, on the contrary, are better described as tasks having a beginning and an end. In these cases, it is very often possible to test whether some fixed goals have been reached. Beside this, when tasks are executed at the same time in a multitasking activity, this can happen in a more or less concurrent way. Namely, when at least two tasks are executed contemporarily, we may think of multitasking as a concurrent activity. Otherwise, when tasks alternate, more or less rapidly, before their goals are reached, we may more precisely think of a sequential multitasking activity. It is easy to foresee that changes in the characteristics of the tasks or in the ways in which multitasking occurs will have different consequences on performance.

Konig, Buhner and Murling [15] made a very similar distinction about multitasking, the one between sequential and simultaneous processing. In their results multitasking was correlated with several cognitive variables, thus showing that successful multitasking activities may be related to efficient working memory, fluid intelligence and to the ability to properly allocate attentional resources.

However, more research is still needed to clarify the complex interactions among these variables and processes. Studies addressing the issue of the relation between learning processes and the level of usability of a teaching system, when the interaction occurs under the circumstances of multitasking activity, are also surprisingly missing.

The study in which Hembrooke and Gay [16] tried to assess whether university students could take advantage by the use of a laptop during classes is a partial exception to this lack of knowledge. In this study, students in a class were free to use their laptop to connect to internet and surf the web while their activity was continuously logged. Results showed that multitasking was not functional to improve learning processes, even for those subjects who had being using their laptop to search the web for issues related to the lecture. However, although the study may be considered quite valid from an ecological point of view, these results are not informative about the way in which students performed their search activity - that is in which kind of multitasking they were operating - and about the level of usability of the sites consulted. As a consequence, it is difficult to say in which way the different variables involved in this experimental setting contributed to determine such results. More importantly, from a practical point of view, we still need knowledge about how to design training system that can be effectively used in learning contexts in which multitasking is likely to occur.

2. THE STUDY

Learning systems having different levels of usability can be more or less effective with respect to their learning aim, depending on the way they are actually used. Usage contexts, in fact, often interact in unpredictable ways with different systems. Therefore, the same system can be more or less effective as functions of several different factors.

Given the increasing penetration of ICTs in every context of our lives, it seems extremely important to try to understand how multitasking can affect the tasks we are engaged in, particularly if learning is one of those tasks [17]. Thus the aim of the present study has been to verify whether and how learning is affected by the usability of the learning systems and by different kinds of multitasking activities, either concurrent or sequential.

2.1 Method

2.1.1 The sample

We have included in the study 223 high school students, belonging to different classes of the Scientific High School Pietro Gobetti, in Florence, Italy.

The students were divided in 6 groups, approximately balanced for age and average grades. There were 120 male and 103 female students. The average age was approximately 16 years old. The average grades for the six groups of students were in the range of 6.2 and 7.0 (in Italy school grades are in the 1-10 range). Most of the students had previously taken either a car or a motorcycle driving license class.

2.1.2 Procedure and materials

The study took place in the high school computer room, which had 22 individual PC workstations with internet connections. All students were asked to learn, individually, as much information as possible from a text about road safety.

The text was structured in order to provide both an overall theoretical background as well as the most relevant information on road safety. It dealt with issues of risk perception and management, and it stressed how driving behavior is affected by a complex interaction between individual, environmental and vehicle-related variables. At the same time, however, detailed and specific information, such as car accident statistics for Italy and Europe, were included in the text. In order to be able to test precisely the outcome of learning, we intentionally included in the text punctual, easy-to-verify, information, e.g. relative to the legal blood alcohol level permitted in Italy, or to the specific effects of several psychotropic drugs.

A first draft of the text was reviewed by two independent researchers in the field of communication and education. These experts were asked to rate, on a seven-point scale, four different aspects of the text: how easy it was to understand, how informative it was, how interesting and how learnable. The text was rated positively on all of the aspects, except for the first, the understandability, which one of the two reviewers (but not the other) rated negatively (see table 1). We thus revised the text according to the suggestions of the first reviewer, to improve its degree of understandability. The revised text was then further assessed by the same reviewers, which agreed that it was now appropriate for our study.

<table>
<thead>
<tr>
<th>understandability</th>
<th>Informative</th>
<th>able to induce interest</th>
<th>learnable</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5</td>
<td>5,5</td>
<td>4</td>
</tr>
<tr>
<td>6,7</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>
The text was used to build two different websites, one specifically designed to have a highly usable interface, the other to have an interface that was difficult to use. To achieve these opposite levels of interface usability, we considered 8 usability design guidelines.

![GUIDA SICURA](image)

These guidelines were drawn from the research literature on user interface design [1] and on e-learning systems design [7]. The usable interface was designed following the guidelines, the other one (difficult to use interface) was designed to violate them. Below we list the design guidelines we considered, along with some examples of possible ways to respect or violate them.

**Visual design.** Usable: color consistency/matching between headlines and corresponding web site sections. Difficult to use: lack of color feedback to signal a section change; need of scrolling the page to view the entire home page.

**Navigation.** Usable: clicking on the header of each page brings the user back to the homepage. Difficult to use: no information on the level of depth within the hierarchy reached browsing the information structure.

**Accessibility.** Usable: considerate/moderate usage of distracting graphic elements not directly functional to the acquisition of information. Difficult to use: using scarcely readable, low-contrast, fonts (similar in color to the background).

**Interactivity.** Usable: when scrolling is needed, the scroll bar is inside the section that has to be scrolled. Difficult to use: need of scrolling the page to view the entire home page.

**Help and documentation.** Usable: the Table of Contents of each section and paragraph is always present on the screen. Difficult to use: lack of information about the text structure.

**Effective learning design.** Usable: user is provided with a representation of a hierarchical structure explaining which part is more logical to study first. Difficult to use: no information is provided to the user about which sections are better to study first.

**Content.** Usable: right balance between text compactness and fragmentation. Difficult to use: the text content is too fragmented in many small paragraphs.

**Able to induce motivation to learn.** Usable: students are given implicit suggestions to first study the sections about risks related to unsafe driving. Difficult to use: the user has to perform too many actions/click to navigate back to the highest levels of the information structure and start learning about new topics.

Both the interfaces, the one designed according to the guidelines and the one that violated them, were then independently evaluated by 4 Human-Computer Interaction experts. The experts used for their assessment the same guidelines that were used to design the interfaces. In table 2 the average evaluations of the two interfaces for each guideline are reported. The ratings were expressed on a 5-point scale, and we can notice that the differences between the ratings for the usable and for the difficult to use interfaces ranged from 1.5 to 2.75.

Except for the features of the interface, the content provided by the two learning systems were exactly the same. The study was designed as follows: three groups of students interacted with the usable interface, and three with the not usable one. For each interface, the usable and the not usable, one group interacted only with the interface, without engaging in multitasking, while the students in the other two groups were multitasking while using the system, either in a sequential or concurrent way. Thus, the experimental design included two between-groups factors: 1) usability, and 2) kind of interaction. The first factor had two levels: 1) usable interface, and 2) not usable interface. The second factor had three levels: i) learning task without multitasking, ii) learning task with concurrent multitasking, and iii) learning task with sequential multitasking.

More specifically, in all of the conditions the students used the system for 30 minutes, trying to learn as much information as possible. In the control/no-multitasking condition the students just interacted with the system. In the concurrent multitasking condition the students, while engaged in learning with the system, at the same time had to chat on Skype™ with one of the experimenters, for three brief sessions lasting approximately 3-4 minutes each. Students were explicitly asked to keep studying the text while they were chatting with the experimenter. In the last condition, the sequential multitasking condition, students were free to keep studying the text or not while chatting with the experimenter, and were given 10 extra minutes to study the text, which approximately corresponded to the time they had to spend chatting. The contents of the chats between each student and the experimenter were approximately always the same and related to: i) the reasons they had considered to apply to that school, ii) their preferred courses, and iii) their preferred music, sports, etc.. Notwithstanding the learning task and, for those in the two multitasking conditions, the conversation with the experimenter, the students did not have to perform any additional task.
At the end of the experimental session, students had to fill in a questionnaire to test their understanding and remembering of the text. Of the 32 items included in the questionnaire, 23 were multiple-choice items (with 3 choices per item), and 9 were open questions. All of the items pertained to specific pieces of information reported in the text.

### 3. RESULTS

A between-subjects analysis of variance was conducted on the scores obtained by the subjects in the post-test questionnaire. The ANOVA considered two factors: Usability (2 levels) and Kind of Interaction (3 levels). Both factors were significant.

The students that interacted with the usable interface had higher scores than those that used the difficult interface ($F(1, 217) = 6.563; p<.01$), a result that lends support to the hypothesis that interfaces that are difficult to use can erode cognitive resources that should be dedicated to the tasks that the same interfaces should instead support.

Also the factor related to the kind of interaction was significant ($F(2, 217) = 3.574; p=.03$). In this case, as shown in figure 2, the significant differences were between the “concurrent multitasking” conditions and the other two conditions. This means that when students had to learn and, every now and then, contemporarily speak with the experimenter, this brought a worsening of the learning performance.

On the contrary, when students had to learn in a condition of sequential multitasking, that is when they had the possibility to stop studying, speak with the experimenter, and then to recover the time spent on speaking, their scores were actually coincident with those obtained when no multitasking is performed. And this result was not affected by the level of usability of the interface adopted.

#### Table 2. Means of the ratings – on a five-point scale – that were expressed by four Human-Computer experts for the two interfaces

<table>
<thead>
<tr>
<th>Usability dimensions</th>
<th>Difficult to use interface</th>
<th>Usable interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>visual design</td>
<td>2.25</td>
<td>4.75</td>
</tr>
<tr>
<td>navigation</td>
<td>1.75</td>
<td>4.25</td>
</tr>
<tr>
<td>accessibility</td>
<td>3</td>
<td>4.75</td>
</tr>
<tr>
<td>interactivity</td>
<td>2.25</td>
<td>4</td>
</tr>
<tr>
<td>help and documentation</td>
<td>2.25</td>
<td>4.5</td>
</tr>
<tr>
<td>effective learning design</td>
<td>2</td>
<td>4.75</td>
</tr>
<tr>
<td>content</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>able to induce motivation to learn</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>2.25</strong></td>
<td><strong>4.375</strong></td>
</tr>
</tbody>
</table>

#### Figure 2. Mean scores for the two interfaces (difficult to use and usable) and the 3 experimental kind of interaction (No MT: No multitasking; Conc MT: concurrent multitasking; Seq MT: sequential multitasking).

The interaction between the two factors was in fact not significant. This suggests that interruptions are not detrimental for the performance of a learning task like the one conducted in this study. This was in fact a learning task in which it was not necessary to store and/or retrieve operational procedures aimed at the attainment of specific goals. In those cases, we could more easily suspect that resuming and completing a procedure after it has been interrupted, may require a consistent effort from the subject, after the allocation of the cognitive resources on another task, due to both the storing of the uncompleted procedure inside the working memory and the resuming of its last steps.

Instead, in the learning task considered here, interruptions did not imply neither an increase in the memory workload nor a frequent, and consequently effortful, reallocation of the attentional resources. It was a quite simple memory tasks in which subjects had to learn as many information items as they were able to. In addition, it must be considered that the task was made even simpler by the fact that those pieces of knowledge, once acquired, did not require further consistent cognitive elaborations. The results would have probably been quite different if subjects had to learn something that forced them to elaborate more or less complex mental models.

It should also be noted that scores in the post-test questionnaire were positively correlated with individual school grades ($r=.22, p<.01$). A result that clearly shows that many variables are likely to have an effect on such a complex phenomenon, variables that depend on both individual characteristics and contextual factors.
4. DISCUSSION AND CONCLUSIONS
In the formerly cited paper of Hemberoke e Gay [16], it was maintained that it is possible to structure training courses in which negative effects of multitasking on learning processes may be mitigated. Among these prospected solutions, one considers viable the possibility that learners are specifically instructed on how to learn. The other is instead related to the fact that, while designing training courses and systems, an occurrence of sequential multitasking should be foreseen and, in some cases, possibly stimulated. Using Hemberoke e Gay [16] same words “if one is adroit at staccato-like browsing, processing multiple tasks simultaneously may not suffer to the same extent” (p. 15).

Both these circumstances have been, at least partially, explored in the study reported here, thus obtaining some evidence that, multitasking is not necessarily correlated with poor learning performances. It is on the contrary possible to maintain that multitasking is likely to show its negative effects only when students interact, in a concurrent way, with systems that are difficult to use. These considerations are clearly strictly referable just to the learning context devised in this study, where specific interfaces, contents, and multitasking activities have been determined: changing those variables, results could have changed evidently and accordingly.

However, basing on these results it is possible to hypothesize which further distance learning circumstances are likely to have negative effects on learning performance, this by making learning task quite hard and sometimes nearly impossible to accomplish. For instance, these are those cases in which, learning material, that is the information that one has to acquire, implies and additional cognitive load on those systems participating at the cognitive elaborations that are realized inside working memory. These learning conditions are more easily likely to occur when structured and complex procedures must be acquired [18], or when multiple relational mental models must be elaborated. By and a large, also a not sufficiently detailed analysis and management of the logical relations connecting the different subtopics of the learning material may imply the same problems. In these cases students may in fact be forced to frequently and, maybe without an evident reason, move from one task to the other, thus continuously and effortfully reassigning attentional resources.

It is thus possible to further define those criteria that in the last years have been proposed and adopted for the evaluation of the level of usability of distance learning systems. And this, in many cases, could be attained by the consideration of the real contexts in which the systems will be used, and basing on the assumption that very often these systems will be used while other tasks are concurrently executed through the interaction with other technology. All the design solutions that will be inspired by the goal of decreasing informational and operational workload, that is those aiming at making more unlike the possibility of overload to occur, are to be considered solutions that, reasonably, will positively affect learning processes.

Assuming this perspective, a more profound analysis of the learning contents that must be delivered through the implementation of distance learning systems appears to be a sound necessity. Not any kind of knowledge may be effectively taught through distance training systems, and this, in many cases, depends on the characteristics of the same knowledge. In addition, it is possible to see as effective those technical and ergonomic solutions that allow the user to keep a trace of what already studied, to clearly see what he/she is studying at a given moment, and that highlight the point in which the system has been quitied, or momentarily neglected, to execute a concurrent task.

However, in addition to these solutions, here just sketched, a probably even more abstract indication seems worthwhile of further thinking, that is the suggestions that indicate us to try to live in environments that are less crowded of often unnecessary technology.

5. ACKNOWLEDGMENTS
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6. REFERENCES


