Reading and understanding a science report through paper and hypertext

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Abstract

Under the perspective that science communication will increasingly be done through the Internet, it is important to understand how users read and understand information in this medium. This study focuses the Web and it examines the effects of presenting a document set (a popular science magazine report) in two different formats: print and hypertext. An experimental protocol was used to assess readers' performance in terms of comprehension of the material, perception of cognitive load, satisfaction and attention to the documents. Hypertext reading lead to poorer comprehension of complementary documents and higher perceived effort to read materials such as tables and graphics. On the other hand, satisfaction with the materials was generally high among all users, indicating that there is no prior rejection of the technology. The present data offer support for theories of disorientation and cognitive load in learning from hypermedia. We suggest that efficient hypertext! s may be built, but in order to do so, authors will have to improve text legibility in the electronic medium.

Paper

Introduction
Internet and the World Wide Web are being increasingly used as a medium for producing and delivering news. Many magazines and newspapers nowadays have an on line version and sell access to their content. Concerning public communication of science, and science journalism specifically, the Web is regarded as a "new space", where authors can “guide” readers through diverse information sources and types (Trench, 2000), and where the general public can access a body of information that was previously “hidden” from them (Peterson, 2001). Either as a news-making or as a dissemination tool, the Web is changing the practice of science writers and making new stories possible, although it has also raised some concerns about source reliability and information quality (Trumbo et al., 2001). Reasons exist to believe that the Web will be adopted as an important medium for publishing science news in the future. Speed, breadth and cost of delivery are important issues that may promote the di! ssemination of this medium (Eveland & Dunwoody, 2001).

Even though some science popularization Web sites are already frequently visited, few data are available on how users actually read, understand, and make use of their content. Therefore, it is not clear whether the Web allows the communication of science as effectively as, or even better than the traditional printed media. On the one hand, authors can use electronic media to provide contextual material, increase the number of information sources, include multimedia contents and establish new forms of communication with the public. These potentialities are interesting and attractive. On the other hand, results from experimental research have shown that multimedia technology is not easily handled. Issues of disorientation, high cognitive prerequisites and lack of experience with technology constitute barriers for users (Dillon & Gabbard, 1998). Thus, although a science popularization Web site may offer a variety of services and contents, it may also happen that readers do not ! actually exploit these possibilities as effectively as they do with traditional print media. Is there any change in meaning making and comprehension processes when we switch from print to electronic media? Does technology influence the perception of science arguments? These important questions remain largely unanswered as of today.

In the context of science popularization, both print and electronic media deal essentially with written language, with large differences in the way textual elements are displayed and

interconnected. Therefore, we start with a brief review of the impacts of computerized presentation on text legibility. Then we turn to the issue of assessing media efficacy in terms of comprehension and learning. Finally, we examine the role of individual variables - such as experience with technology and content area expertise - on the effectiveness of computer-based reading activities.

Legibility: hypertext X print

"Legibility" can be defined as the adequacy between a given text and its intended readership (Labasse, 1999). There are, as Labasse writes, several "levels of legibility", ranging from surface to deep levels, the former including physical characteristics of the materials (i.e., typography, colors, contrast, and so forth). The presentation of text on electronic media is known to affect legibility on both levels.

In the current stage of technological development, the presentation of text on computer screens has a negative impact on surface legibility (Dillon, 1994). As a consequence, reading on a computer screen is about 20% slower than reading on paper (Nielsen, 2000). In order to present a satisfactory level of legibility, computer presentation requires the use of a greater contrast, less information density and bigger characters (Caro & Bétrancourt, 1998). Currently, few Web sites put these principles into practice. Screen legibility can also be improved through the use of high definition screens (Gould, Alfaro, Finn, Haupt & Minuto, 1987), but for most users this technology is still not available.

Visualization of information (the way information is displayed by authors and assessed by readers) is another source of difference between print and computer presentation. Print technologies allow the use of large display areas (e.g., newspaper pages, posters), and a straightforward perception of text extension and content (e.g., stacks of books and papers on a desk). With computer presentation, the display area is bound by the physical size of the computer screen. Text resources are represented by symbols, e.g., icons in a file folder or links in a hypertext menu. When browsing through printed materials, contents can be easily scanned; when browsing a hypertext, the user has to select links in order to explore the contents. Additional difficulties are the need to perform mouse clicks in order to go from one page to another, and the need to use the scroll bar while reading. At least one study has shown that these two conditions (paging and scrolling), when combined, increase! reading time and decrease memory for information, although no significant differences were found for either device used in isolation (Van Oostendorp & Van Niemwegen, 1998).

Hypertext links also allow for the building of nonlinear text structures. While pages in a printed text are organized according to a linear pattern (i.e., numbered series), in hypertext pages can be organized as a nonlinear network. Even though nonlinearity has sometimes been praised as a means to free the reader from the rigid organization of printed materials (Bernstein, Joyce & Mylonas, 1992), excessive nonlinearity is known to cause disorientation and cognitive overload (Gordon et al., 1988; Wright, 1991). In fact, some authors argue that linearity is not a technological “constraint” of printed materials, but a way to help readers follow the author’s reasoning and extract main ideas from a text (Charney, 1991; Dillon, 1996). There is a “need” for some linearity, which comes with the need to understand the concepts underlying the linguistic message (Eveland & Dunwoody, 1998; Foltz, 1996). Or, as Beaugrande (1997) writes, linear principles are inscribed in language itself.! These principles, such as pacing, look-back and look-ahead, merging and listing help the user control the several levels of complexity in a text, and play an important role in text interpretation. Indeed, a recent study by Eveland and Dunwoody (2001) has shown that disorientation can be reduced by using print “cues” in hypertext, such as page numbers and summaries. In any case, reducing nonlinearity helps improve hypertext legibility.

Because structuring contents seems more important in hypertext than in print, several authors have tried to design and visual structures that facilitate navigation in hypertext (Britt, Rouet & Perfetti, 1996; Dee-Lucas, 1996; Jonassen & Wang, 1993; Pohl & Pulgarthofer, 2000). So far,

some interesting results were obtained, but the data are not always conclusive. In summary, research shows that hypertexts often present poor legibility, reduce reading comfort and require good knowledge of text structure to allow effective navigation through links. So far, however, studies comparing text and hypertext presentations have yielded rather inconclusive results, due in large part to the variety of research methods and criteria used to assess the efficacy of either media.

Media efficacy

The issue of media efficacy cannot be fully resolved based on the simple quantitative performance measures typically used in legibility studies. More qualitative aspects of users' perceptions and behaviors must also be taken into account.

Attitudes toward a technology can predict the degree of its adoption in a given population. In a survey of science writers, Trumbo et al. (2001), found that attitudes toward the Web in its early years were a predictor for its adoption at the end of the 90's. Based on the paradigm of Diffusion of Innovations Theory (Rogers, 1995), they measured journalists' self-declared "favorability" to the Web, in 1994, and compared it to connectedness and frequency of Web use, in 1999. A regression analysis showed that the attitude (predominantly favorable) declared in the first survey corresponded to a high growth in technology use in the second. A favorable perception of the Web in its early years could, thus, predict its massive adoption by these journalists five years later.

However, a positive attitude or even heavy use do not mean blind faith in the medium. By means of semi-guided interviews, Trumbo et al. verified that the heaviest users were also the ones who most mistrusted the information available on the Web. These professionals tended to see the Web and the e-mail as great tools for news making, but they are also skeptical, because the Web may easily lead to dispersion, waste of time and to non reliable information or illegitimate sources.

Cognitive load can be defined as the amount of effort necessary to identify and coherently integrate information from a text (Sweller, Chandler, Tierney & Cooper, 1990). Early investigators of hypertext argued that hypertext usage could result in excessive cognitive load (Conklin, 1987; Wright, 1991). For example, the lack of information about a link's content causes the sensation, often cited by hypertext users, of not knowing "what's behind the door" (Gordon et al., 1988) or "getting lost in hyperspace" (Edwards & Hardman, 1989).

More recently, Eveland & Dunwoody (2001) compared the use of hypertext versus print for learning science subjects and did not observe any significant differences in cognitive load across media. The perception of cognitive load was not greater for hypertext than for paper. These results were interpreted as "limited evidence" that hypermedia reduces learning because of factors such as cognitive load and disorientation (Eveland & Dunwoody, 2001, p. 66). It is important to note that this study used a measure of "self-reported cognitive load", that is not exactly the same as "cognitive load" in other works, as the authors themselves emphasized. Just like in previous studies, it may be asked whether the particular definition of cognitive load used by the authors, or even the type of items used in their questionnaire may have had an impact on the observed pattern of effects.

Finally, many hypertext studies have attempted to assess the respective efficacy of text vs. hypertext by evaluating the outcome of media usage in terms of comprehension, learning or memory for content (Lehto et al., 1995; Marchionini & Crane, 1994; Jacobson and Spiro, 1995). Again, the outcome seems to depend on the type of measures used in the experiments. To mention an example, Marchionini and Crane (1994) found greater lexical variability in texts produced by users of a hypertext version of an encyclopedia, but results were not significant in other tasks.

To summarize, the observed effects of hypertext depend to a large extent on the type of measure used to assess its effectiveness. So far, most studies have used a small number of dependent measures. Moreover, the tools used to assess attitudes, cognitive load or comprehension are highly variable and sometimes rather simplistic. A more accurate profile of the benefits and limitations of reading hypertext could be obtained by using a variety of measures within a single experimental design.

Study design and hypotheses

The literature on hypermedia learning shows that a straightforward adoption or rejection of hypertext as a reading format is not possible. More research is needed to determine the advantages and disadvantages of the electronic medium. Because the Web is already being used for science communication, with a potential for growth, it is interesting to know how current hypertexts impact reading, in terms of comprehension of the material. To answer this question we conducted an experiment comparing a print and an electronic version of a popular science magazine report.

The report was published by Supertinteressante magazine on April 2001. It was about the approval of an abortion drug (mifepristone) by the Food and Drug Administration (FDA) and its consequences for the public debate in Brazil, where abortion is illegal. The report was formed by a set of documents, namely: a feature (main text) and complementary documents (e.g., interviews, tables and graphics). The complementary documents contained important support information to the arguments presented in the main text (e.g., a table comparing tolerance for abortion in some countries and the testimonies of two women who had experienced abortion). In print, these documents were presented along with the main text, with explicit references to them in the text (e.g., "see table on the next page"). In the hypertext version, these documents were presented in a menu, placed at the beginning of the main text. Each document was identified by the title but no additional information was available (e! .g., "comparative table", "animated graphic"). All links opened up in a smaller pop up window and one of them was animated with Flash™, showing chunks of text in small characters, that could be zoomed with a mouse click.

Based on our review, we selected a number of hypotheses to compare the legibility of the report, in print and hypertext.

Because access to the complementary documents was not as straight in hypertext as in print, we predicted that perception of cognitive load would be greater and comprehension of documents would be lower for users of the hypertext version.

Specifically, we made the following predictions:

Hypothesis 1: Effect of presentation condition on comprehension. Users of hypertext will obtain a lower score on comprehension compared to print users. A control group, without reading materials at the time of answering questions, will obtain a much inferior score than the two other groups.

Hypothesis 2: Effect of Web experience. On the hypertext version, comprehension of complementary documents will present a positive correlation with users' experience with the Internet and the Web.

Hypothesis 3: Effect of previous knowledge. Previous knowledge will present a positive correlation with comprehension, no matter what the presentation condition is.

Hypothesis 4: Effect of presentation condition over distribution of attention. Hypertext users will pay more attention to the main text and less attention to the complementary documents, when compared to the users of print and the control group.

Hypothesis 5: Effect of presentation condition on perception of cognitive load. Hypertext users will report a higher level of perceived cognitive load, compared to users of print and to the control group.

Hypothesis 6: Effect of presentation condition over satisfaction. Hypertext users will consider the report less positively than readers of paper and of the control group.

Method

Participants

Fifty-nine undergraduate university students participated in the experiment as part of a non-mandatory class assignment. They were fourth-year journalism students in a private university in the State of São Paulo (Brazil). Age, education and socioeconomic level of participants corresponded to those of the magazine's target public. Students who had previously read the report were excluded from the analysis.

Materials

Pretest questionnaire. A questionnaire was designed in order to assess participants' technological experience, prior knowledge of the subject, familiarity with Superinteressante magazine and the text, and their overall opinion on the issue of abortion. The clarity and validity of the questionnaire were assessed in a pilot study involving eight students drawn from the same population (these students did not participate in the experiment).

Technological experience was measured by means of six questions, including: years of Internet use; frequency of use of selected sites (using a 5-point scale, ranging from 1="never used" to 5="many times a day"), knowledge of technical concepts (e.g., "a cookie is..."), knowledge of search sites. Most questions were either multiple choice or scale-like.

Initial knowledge about the subject was measured by means of seven multiple-choice questions, based on information contained in the report. An example of these questions is: "The abortion pill is: the same as 'the day after pill'; a medicine against ulcer also used for abortion; a medicine recently approuved in the USA; I don't know".

Familiarity with the magazine and the report on abortion were measured by means of two multiple choice questions: "How often, on average, do you read the magazine?" and "Did you read the report 'The pill of discord'?". Readers who had read the report were excluded from the sample.

Opinion on abortion was assessed through a 5-point scale question: "In which point of this scale would you place your opinion on abortion?", ranging from "1= Must be totally legalized" to "5= must be totally prohibited". The purpose of this item was to control for the possible prevalence of radical opinions ("pro" or "against") and whether they changed after reading the report. Such a scenario was not verified.

Reading materials. Paper version and a hypertext version of the report entitled "The pill of discord", originally published by Superinteressante magazine on April 2001. Readers of the paper version used copies of the original magazine and were assigned to a standard classroom . Readers of the hypertext version used the electronic version of the report, previously downloaded to avoid connection problems. They read the hypertext on Pentium 166 PC computers with 14-inch screens. Readers of the hypertext version were assigned to a computer classroom beside the standard classroom. Both classrooms were familiar to the students. Figure 1 shows both versions of the report: paper and hypertext.

Figure 1: Print and hypertext versions of the report "The pill of discord"

Post-test questionnaires. The post-test questionnaires measured five variables: comprehension, perception of cognitive load, satisfaction with the reading experience, perception of the relative importance of each document, and attention granted to each document during the study phase. The questionnaires were pre-tested with three students from the same group as in the pre-questionnaires pilot study.

Comprehension was assessed through 17 multiple-choice questions. Eight questions dealt with information presented in the feature text, and 9 dealt with information presented in the documents.

Perception of cognitive load was measured through a list of eight assertions that participants had to evaluate using a 5-point Likert scale. Four assertions were adapted from Eveland and Dunwoody (2001), and referred to cognitive load in general terms (e.g. "I had difficulty understanding how the information was structured into a coherent story"). The four others were more specifically related to the tasks and the materials used in the present study ("The tables and infographics were easy to read and understand", reversed item).

Satisfaction with the reading experience was measured through a list of five assertions about visual attractiveness, interest and easiness of the materials, and their contribution to the participant's understanding of the issue.

The participants rated their perception of importance and attention paid to each document through 5-point Likert scales ("unimportant" to " very important", and "not read" to "read attentively", respectively).

Procedure

The experiment was run in two sessions separated by a one-week interval. The first session was dedicated to the pre-test questionnaire, and the second session was dedicated to the reading task and post-test questionnaires.

Pre-test session. The pre-test session was run collectively in the participants' usual classroom. Before they answered the pre-test questionnaire, students were informed about the research project and asked to give sincere answers. Then the questionnaire was distributed and students were given 15 minutes to answer. The 15-minute delay was based on the results of the pilot study. All the students managed to complete the questionnaire within the allotted period of time.

Reading and post-test session. Based on their scores on the pre-test questionnaires, the participants were assigned to a hypertext group (G1), a print group (G2) or a control group (G3). The three groups were balanced for age, gender, prior experience with technology and prior knowledge of the subject.

Results
The results are presented in an order consistent with the hypotheses. Unless mentioned otherwise, all the results are statistically significant at a p level of .05.

Comprehension.
Figure 2 shows the average comprehension score in each of the three groups for the main feature and the documents.

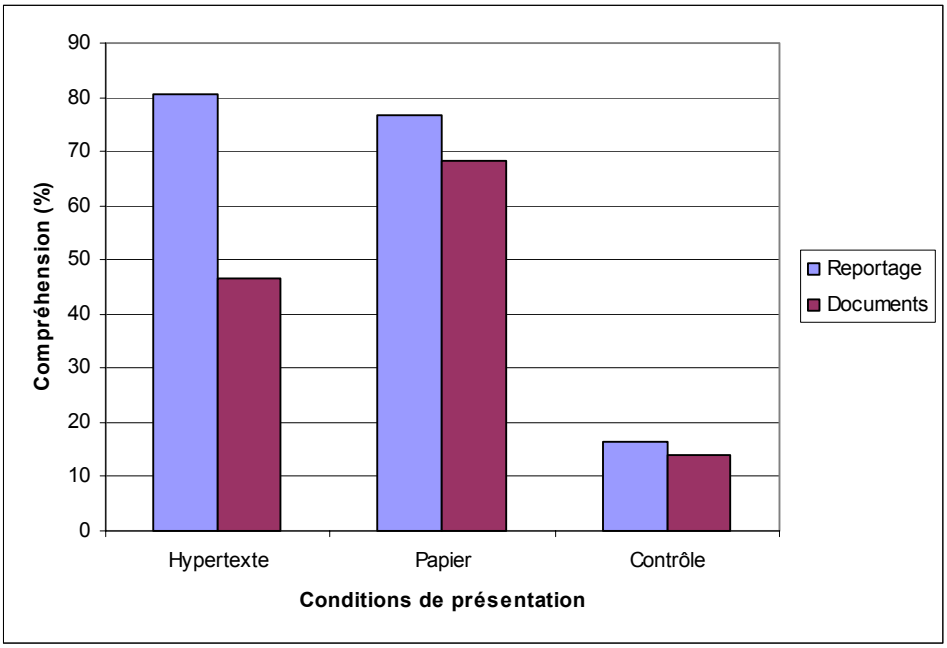

Figure 2 : Comprehension of the main text and of complementary documents by experimental condition

The overall level of correct answers in G3 was rather low (15%), indicating that reading the materials was indeed necessary for students to provide correct answers. In the two other groups, the comprehension level was much higher (63 and 72% on average), which suggests that correct answers could actually be provided based on the content of the texts. However the comprehension level of the documents was lower for students in the hypertext group than for those in the print group.

A two-way analysis of variance with Group (G1-hypertext, G2-print, G3-control) as a between-subject factor and Question Type (feature text, documents) as a within-subject factor showed a significant effect of Group. Groups 1 and 2 obtained scores significantly higher than group 3, but did not differ significantly from each other. The analysis of variance also showed a significant interaction between the Group and Question Type factors. Group 1 (hypertext) obtained lower results than Group 2 (print) on questions about the documents (47% and 68%, respectively). However, groups 1 and 2 obtained similar results on questions about the main feature (80% and 70%, respectively).

In order to test hypothesis 2 (effects of students' technological experience and prior knowledge on their comprehension), we calculated Pearson' correlations between pre-test scores and the total comprehension scores in each group. We obtained a non significant positive correlation between technological experience and comprehension in the Hypertext Group (r(15)=0,24). Therefore, our prediction that prior experience with the technology would improve content

comprehension in the hypertext condition was not fully supported, despite a trend in the expected direction.

In accordance with hypothesis 3, we obtained significant positive correlations between prior knowledge and comprehension in group 1 (hypertext) and 3 (control). Participants with a higher level of prior knowledge were better able to answer comprehension questions either after reading the hypertext (group 1) or before reading the print version (group 3). In group 2, however, we obtained a significant negative correlation between participants' prior knowledge and content comprehension. This unexpected result is quite counter-intuitive and difficult to explain. Complementary analyses suggest that some participants with a high level of prior knowledge did not devote much attention to the materials and hence obtained low comprehension scores. Because of the small sample size, this may have caused an apparent negative correlation.

Distribution of attention

A two-way analysis of variance with group as a between-subject factor and text type as a within-subject factor showed that the participants granted more attention to the main text than to the documents. More than 80% of the participants in the hypertext and print groups declared that they had read the feature text "attentively" (i.e., the maximal score on the five-point Likert scale). In contrast, the percentage of participants who declared reading the complementary documents attentively was comprised between 0 and 50 %, depending on the group and on the document, with an average of 32%, 34% and 28% in groups 1, 2 and 3, respectively.

The Group factor had no main effect, nor did it interact with text type ($F<1$). Thus, hypothesis 4, that readers in the hypertext group would devote selectively more attention to the main text than to the documents, compared to the other groups, was not exactly supported. Participants in the hypertext group did devote more attention to the feature than to the documents, but so did the participants in the two other groups.

There are reasons to expect that a high attention to the documents would result in better comprehension scores, since these documents presented unique and important information about the role of the mifepristone and the debate over its use. Indeed, we observed significant positive correlations in the hypertext and print groups. The lack of such correlation in the control group is due to the fact that these students answered the questions prior to reading the texts.

Thus, in the two groups where students read the materials prior to responding to the questions, there was a significant relationship between the attention students devoted to the documents and their actual comprehension of these documents. Students who read the documents "quickly", "in a glimpse", or simply ignored them obtained lower comprehension scores than those who read them "attentively".

Perception of cognitive load and satisfaction

For each of the cognitive load and the satisfaction scales, a global score was computed by summing up the ratings of each item, and converting the total into a percentage of the maximum possible score. For the cognitive load scale, ratings of the positive items were reversed so as to obtain a homogeneous scale. The same was done for the negative items of the satisfaction scale.

Perception of cognitive load was rather low (20-40%), whereas the satisfaction was high. Analyses of variance performed separately for the two dimensions showed that the presentation condition had a significant effect on the perceived cognitive load. Group 1 (hypertext) had higher cognitive load estimates than Group 2 (print) and Group 3 (control). The latter two groups were not significantly different from each other ($F<1$). This pattern of results fully support hypothesis 5 that reading hypertext would result in a higher cognitive load compared to any print condition.

Concerning the satisfaction scale, the analysis of variance did not show any significant difference across groups ($F<1$). A vast majority of students gave very positive appreciation of the contents

of the materials and quality of the artwork. This appreciation was not significantly lower in the hypertext group. Thus, hypothesis 6 was not supported by the data.

The higher cognitive load observed in the hypertext condition was mostly due to three rather specific items: accessibility of tables and graphics, content and size of the texts, and readability of the data in the animated diagram. Among the first four items, adapted from the study by Eveland and Dunwoody (2001), only the "feeling of being lost" obtained a significant percentage of agreement (44% in group 1). The three others gathered a mere 10% of agreement or less. Our result is consistent with the authors' findings, but it does not necessarily mean that there are differences in cognitive load across media are insignificant. Rather, it could be that the items used by Eveland and Dunwoody were not fully adequate to measure cognitive load.

Conclusions

The present experiment found evidence of poorer legibility in hypertext compared to print. Under the same conditions and using the same materials, hypertext readers performed less well in the comprehension of complementary documents than did print readers. The difference, though, was not significant for the comprehension of main text of the report, which was actually a little higher for hypertext users. This pattern suggests that reading hypertext does not prevent comprehension, but that better legibility conditions are required in order to maintain the same efficacy as offered by print.

The poorer comprehension of complementary documents among hypertext readers seems directly related to the effort required to manipulate and read these documents, particularly tables and graphics. We suggest that within long texts, it is not adequate to include detailed and/or animated graphics. Moreover, menus are probably not an adequate presentation format for complex tables and graphics related to a main text. Displaying these graphics along with the text is maybe better or offering more information on the links is probably a better option. This issue is to be verified.

One limitation of this study is that the experiment was done using a single item: print and hypertext version of the Superinteressante report on the abortive pill mifepristone. Some of the results may be linked to this particular content or to the particular design options chosen for each version. For instance, the highest differences in cognitive load between the print and the hypertext version were due to items rather content-specific. Further experiments comparing print and hypertext versions of a variety of materials are needed before general conclusions can be drawn.

Footnotes: "Hypertext" is the concept set phrase by Ted Nelson (Nelson, 1981) to refer to blocks of text connected by electronic links, where "hyper" meant "space with 'n' dimensions". Later on, appeared the concept of "hypermedia", which, according to Landow (Landow, 1997), is a simple extension of the traditional concept, by including multimedia (imagens, animations, sounds). Landow uses indistinctly both "hypertext" and "hypermedia" to refer to an information medium connecting verbal and non verbal information. In this paper, we decided to use the term "hypertext", because it represents better the variables and processes studied in our experience, but we include multimedia information in this concept.

We acknowledge Superinteressante magazine for kindly giving us print copies for the experiment.

Acknowledgements

The work presented in this paper is part of the first author's doctoral dissertation which was supported through a grant from the Coordenaçao de Aperfeiçoamento dos Programas de Pos-graduaçao (CAPES, Brazil). The second author's participation was supported through a grant

from the program "Société de l'Information" of the Centre National de la Recherche Scientifique (CNRS, France).

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