Investigating paper vs. screen in real-life hospital workflows: Performance contradicts perceived superiority of paper in the user experience

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Abstract

Introduction: All hospitals in the province of Styria (Austria) are well equipped with sophisticated Information Technology, which provides all-encompassing on-screen patient information. Previous research made on the theoretical properties, advantages and disadvantages, of reading from paper vs. reading from a screen has resulted in the assumption that reading from a screen is slower, less accurate and more tiring. However, recent flat screen technology, especially on the basis of LCD, is of such high quality that obviously this assumption should now be challenged. As the electronic storage and presentation of information has many advantages in addition to a faster transfer and processing of the information, the usage of electronic screens in clinics should outperform the traditional hardcopy in both execution and preference ratings.

This study took part in a County hospital Styria, Austria, with 111 medical professionals, working in a real-life setting. They were each asked to read original and authentic diagnosis reports, a gynecological report and an internal medical document, on both screen and paper in a randomly assigned order. Reading comprehension was measured by the Chunked Reading Test, and speed and accuracy of reading performance was quantified. In order to get a full understanding of the clinicians' preferences, subjective ratings were also collected.

Results: Wilcoxon Signed Rank Tests showed *no significant differences on reading performance* between paper vs. screen. However, medical professionals showed a significant (90%) *preference* for reading from paper. Despite the high quality and the benefits of electronic media, paper still has some qualities which cannot provided electronically do date.
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1. Introduction and motivation for research

All the hospitals in Styria (Austria) have been equipped with highly sophisticated enterprise Hospital Information Systems. Every medical workplace is outfitted with high-quality visual

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display units. Consequently, now that almost all information is available electronically one would assume that the paper consumption in the hospitals is significantly reduced; instead we have observed an *increase*.

During our observation of the medical workflows, we were able to see that medical professionals preferred to print their findings on paper, expressing a preference to reading from paper rather than from a screen. This observation of practical evidence was the initial motivation for carrying out this study.

The comparison of visual performance of *computer screens* vs. *paper* has been studied since early computers have been used in work places but there is still a considerable need for a critical examination of visual performance from screen in a *real-life work setting*, especially in a *hospital* real-life work setting. In this study, it was undertaken with hospital employees as participants and original and authentic reading material used in medical workflows in hospitals.

At first, we provide an overview of previous screen vs. paper comparison studies (Section 2.1), followed by a description of information presentation on electronic displays (Section 2.2) and the importance of information presentation for real-life workflows (Section 2.3).

2. Background and related work

2.1. Screen vs. paper

As early as the 1980s, studies dealing with the comparison between screen and paper emerged in the scientific community, reacting to the basic change in *methods of displaying information* occasioned by the introduction of the Personal Computer (PC) across office sites (for an overview, see Mills and Weldon, 1987; Dillon, 1992; Schlick et al., 2008, in press). With this electronic shift, a global speeding up of workflows was expected: with the use of electronic data processing, large text and databases can be displayed and edited easily. The flexibility and versatility of computers have removed many of the limitations of data representation and one would have expected paper and ink to disappear with the advent of the so-called *paperless office* (Sellen and Harper, 2001; Thomas, 2006). However, our everyday experience shows that this prediction was off-target or, at least, premature.

There may be many reasons to account for this phenomenon. Gladwell (2002), for example, holds the "*social life of paper*" to be responsible, i.e., as he calls it "the resistance of people's highly trained reading and handling habits withstand changes". In addition, paper is extraordinarily suited for the reading process, i.e., it is tangible (it can be picked up, readers can flip through it), it is spatially flexible (it can be easily moved on the desk and can be suited to individual reading habits as regards size and portability) and it can be tailored to allow readers to make notes, annotations and add bookmarks, without altering the original text. From a cognitive point of view,

the reading comfort and the visual quality of paper as a medium of presentation is very high, possibly because it is the result of a long evolutional process. Consequently, paper can be regarded as an outstandingly suitable display with regard to visual ergonomic demands. It provides high contrast and resolution with neither disturbance by glare, screen reflections or flicker (Ziefle, 2009).

On the other hand, all the advantage of digital documents is evident and undisputed (easy storage, search, transmission and access). However, the reading comfort and ease of information intake has been considerably limited by restrictions of visual display quality, a situation which is changing with the tremendous increase in display technology. Today's electronic media can no longer be compared to the screen quality of VDUs produced 30 years ago. The bulky Cathode-Ray-Tubes (CRTs), display technology which represented the cutting edge-technology of the last century, lost ground continuously to the LCD technology.

During the last years, the quality of Liquid Crystal Displays (LCD)-technology has improved continuously (MacDonald and Lowe, 2003; Schlick et al., 2008; Oetjen and Ziefle, 2009) and meanwhile, LCD-technology is the prevailing state-of-the-art display technology in offices and it also comprises the continuously growing sector of mobile small screen devices (mobile phones or personal digital assistants, PDA).

Since the first evaluation studies of different displays were published (Muter et al., 1982; Wright and Lickorish, 1983; Kruk and Muter, 1984; Heppner et al., 1985; Wilkinson and Robinshaw, 1987), a huge number of studies have dealt with, and still deal with, the fundamental question as to which display type assures the highest reading comfort and the best visual performance (Miyao et al., 1989; Dillon, 1992, 1996; Hollands et al., 2002; Oetjen and Ziefle, 2004, 2007, 2009; Holzinger and Errath, 2007).

2.2. Information presentation on electronic displays

There is also a long history of studies concerned specifically with the evaluation of visual display quality (for an overview see Dillon, 1992; Schlick et al., 2008), basically pursuing two prominent research goals.

The first research approach refers to the comparison of displays with respect to effectiveness and efficiency of encoding and processing information. This type of research typically consists of a benchmark of the traditional hardcopy, in comparison to different types of electronic displays, for example CRTs and LCDs (e.g. Creed et al., 1987; Gould et al., 1987; Heppner et al., 1985; Ziefle, 1998; Menozzi et al., 2001). Aspects of readability and legibility in different texts were scrutinized (e.g. Ishihara et al., 1993; Dillon et al., 2006; Holzinger and Errath, 2007).

The second research approach addresses specific factors affecting visual performance. In this context, effects of *luminance contrast* (e.g. Näsänen et al., 2001; van Schaik and Ling, 2001; Sheedy et al., 2003; Ziefle et al., 2003),