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# Visualization of ergonomic guidelines — A comparison of two computer aided systems to support vehicle design

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## Abstract

Guidelines are used in information and quality management systems to ensure high quality by supporting design, production and communication processes. These guidelines can be presented as a conventional system on an intranet suitable for printouts, visualized as a traditional text-based report with a list of headings accompanied by tables and pictures or presented as paper documents in manuals or binders. Such approaches do not always correspond to some companys' requirements for usability. However, multimedia techniques can be used to visualize and let users interact with the information through hyperlinked text, pictures, and animations. The aim of this study was to design a computer aided system of ergonomic guidelines visualized by means of interactive multimedia technology based on cognitive theories and practical examples. Furthermore, the *efficiency* in and *attitudes* towards using the interactive multimedia system were evaluated and compared with a conventional system which visualized ergonomic guidelines in the form of a traditional report on scrollable web pages. The interactive multimedia system was the result of a participatory design process with experts and potential users in collaboration with Saab Automobile. The system was, in general, faster to use with lower dispersion in performance speed and number of incorrect answers compared to the conventional system. No statistically significant differences were found between males and females or between the five groups of potential users. In addition, the interactive multimedia system was experienced as more enjoyable to use, which is likely to promote interest and learning about ergonomic issues.

## Relevance to industry

The results from this study can be used to design and improve visualization of ergonomic guidelines on an intranet, increase efficiency, and engender a positive attitude towards using ergonomic information.

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**Keywords:** Ergonomic design guidelines; Field studies; Interactive multimedia system; Intranet; Vehicle design; Visualization of information

## 1. Introduction

Guidelines are used in information and quality management systems to ensure high quality by supporting design, production and communication processes. These guidelines are often visualized in the form of a traditional text-based document with a list of headings accompanied by tables, pictures and drawings. They are presented as paper documents or on an intranet suitable for printouts, e.g. paper documents converted to PDF format (Edwards and

Gibson, 1997; Huarng et al., 1999; Blomé et al., 2003). However, these do not correspond to some company's requirements for easily understandable and accessible information. The extensive documentation of quality management systems can appear meaningless and time-consuming to the users (Edwards and Gibson, 1997; Karlun et al., 1998; Chaudhuri and Acharya, 2000). Furthermore, studies focusing on ergonomic knowledge available in guidelines and documents have shown that these are often hard to acquire, are incomplete or inadequately suited to the previously mentioned processes (Simpson and Mason, 1983; Woodcock and Flyte, 1998). An ergonomic guideline could, for instance, offer recommendations

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regarding several aspects such as dimensions, location, and visibility for push buttons in an instrument panel.

The access to guidelines has traditionally been associated with the physical handling of printed media, but new possibilities to present information have emerged along with the development of new technology and Internet. Documents in a traditional format suitable for printouts can easily be converted into scrollable pages on a company intranet, but they offer few benefits compared to printed paper documents with the exception perhaps of easy updating, search functions and widespread distribution on a network of computers. Web technology however opens up many presentation possibilities and lets users *interact* with the information in guidelines through hyperlinked text and pictures, search functions, sound, and animations. The potential for multimedia in ISO 9000 quality systems is, according to a study by Edwards and Gibson (1997), particularly apparent when it comes to training exercises, which can include competency and assessment requirements, and which are available quickly and conveniently at any location. Computer-based team training proved to be as effective as traditional instructor-based team training for aircraft maintenance technicians (Kraus and Gramopadhye, 2001). Likewise, an evaluation of alternate learning systems in an industrial engineering course showed that there were no significant differences between the three forms of instruction: classroom, synchronous and asynchronous (Singh et al., 2004). However, there is still a need for further research to clarify the design and benefits of computer-based learning systems.

The design of suitable visualizations can be supported by practical guidelines for interactive web design, (e.g. Shneiderman, 1998; Nielsen, 2000), as well as by research on how multimedia presentations can increase the effectiveness of processing information by applying cognitive principles such as dual coding. According to the dual coding theory, mental structures are associative networks of verbal and imaginal representations, as well as the mental processes involved in the development and activation of those structures (Clark and Paivio, 1991). The verbal system contains visual codes that denote concrete objects and events as well as abstract ideas in a serial or sequential manner, whereas the imaginal or nonverbal representations are analogous or perceptually similar to the events that they denote rather than arbitrary symbols (Clark and Paivio, 1991). For example, “walking” could be symbolized as the word itself in a verbal system, whereas a picture, drawing or an animation could illustrate “walking” in a nonverbal system. Furthermore, presenting information in separate modalities (e.g. animation with narration), and temporally and spatially coordinated has resulted in improvements in cognitive processing (Moreno and Mayer, 1999).

Another cognitive principle is the theory of visual argument, which Robinson and Kiewra (1995) refer to when they suggest the use of diagrams, maps, charts, and graphs. These communicate information through indivi-

dual elements and arrangement of these elements in space, making it easier for users to perceive and understand relations and patterns than text does. Furthermore, the conjoint retention theory suggests that maps should be used before text or narration to facilitate learning of the information presented (Vekiri, 2002).

By applying the theoretical principles of dual coding, visual argument, and conjoint retention about graphical design, research suggests that graphics are effective learning tools only when they allow readers to interpret and integrate information with a minimum of cognitive processing (Vekiri, 2002). This corresponds to Schnotz and Lowe's (2003) suggestion of an emphasis on the effects of different kinds of information representation such as texts and graphics (either static or animated) on comprehension and learning rather than striving for technical media effects per se.

Recent research indicates that multiple external representations and modalities are not always beneficial for learning (Schnotz and Lowe, 2003). Furthermore, user characteristics such as prior knowledge, visuospatial ability and individual strategies to extract information also influence learning with graphical displays (Vekiri, 2002). In order to design relevant information systems and avoid getting lost in the novelty of online instructions, Weston et al. (1999) suggest five categories of instructional principles in the context of online learning: Instructional Design, Subject Matter, Language, Presentation and Considerations for online context. It is also possible to focus on usability factors when designing an information system for online learning.

The ISO standard for guidance of usability considering ergonomic requirements for office work with visual display terminals (ISO, 1994) defines usability as, “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.” In order to consider usability among the users of information systems, Löwgren (1993) suggests the REAL approach: Relevance to users' needs, Efficiency in carrying out tasks, subjective Attitudes, and how easy users Learn and remember skills over time. The REAL approach overlaps the ISO definition since the relevance and attitude factors are similar to the effectiveness and satisfaction factors for specified goals in the ISO standard. Thus an evaluation according to the REAL approach would be suitable for examining the usability of a visually displayed information system.

A participatory approach is recommended to successfully integrate users' needs when designing future workplaces and quality systems (Karlton et al., 1998; Eklund, 2000). Wilson and Haines (1997) define participation in the context of ergonomics management programs at work as, “The involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals.”

Thus, different visual presentation techniques are recommended depending on the type of information and

users of that information. Suitable visualizations have been developed to present data in different fields, e.g. social and economic statistics often visualize quantitative information with graphs and charts; geographic sciences utilize spatial data and maps (Orford et al., 1999); whereas medical and biological sciences use photos and drawings to explain qualitative information such as biological details (Moore, 1992). Some travel guides (Tillier, 1993) use different types of visualization to present cities by means of integrated photos and text in maps. In addition, multimedia interactive animations, games and sounds are sometimes used in education to explain scientific principles as well as accident plans (Macaulay, 1996; Horn and Werner, 2000).

It would be beneficial if ergonomic knowledge in guidelines and documents was easy to find and interpret, and even enjoyable for intended users: human factor engineers, design engineers, designers and new employees. An information system of ergonomic guidelines based on findings and applications of multimedia learning and visualization techniques designed with the participatory involvement of users was considered a successful approach to visualizing ergonomic guidelines.

The aim of the study was to design a computer aided system of ergonomic guidelines visualized by means of interactive multimedia technology based on cognitive theories and practical examples. The *efficiency* in and

*attitudes* towards using the interactive multimedia system were also evaluated and compared with a conventional system which visualized ergonomic guidelines in the form of a traditional report on scrollable web pages.

## 2. Materials and methods

### 2.1. Two systems of ergonomic guidelines

#### 2.1.1. Ergonomic guidelines visualized as a traditional report on an intranet

In order to explore the preferable manner for visualizing ergonomic knowledge in guidelines and documents on an intranet, field studies were carried out at Saab Automobile, a company that designs and manufactures cars for the global market. The company was located in Sweden and had approximately 8500 employees when the study was performed. The company had a conventional information system of ergonomic guidelines on the intranet, organized as a traditional report consisting of 151 pages. An alphabetic list of hyperlinked headings was connected to different groups of ergonomic guidelines and specific ergonomic guidelines. As Fig. 1 illustrates, the information of the ergonomic guidelines was presented on several scroll-down pages without hyperlinks and animations but with headings, text blocks, tables, and black and white

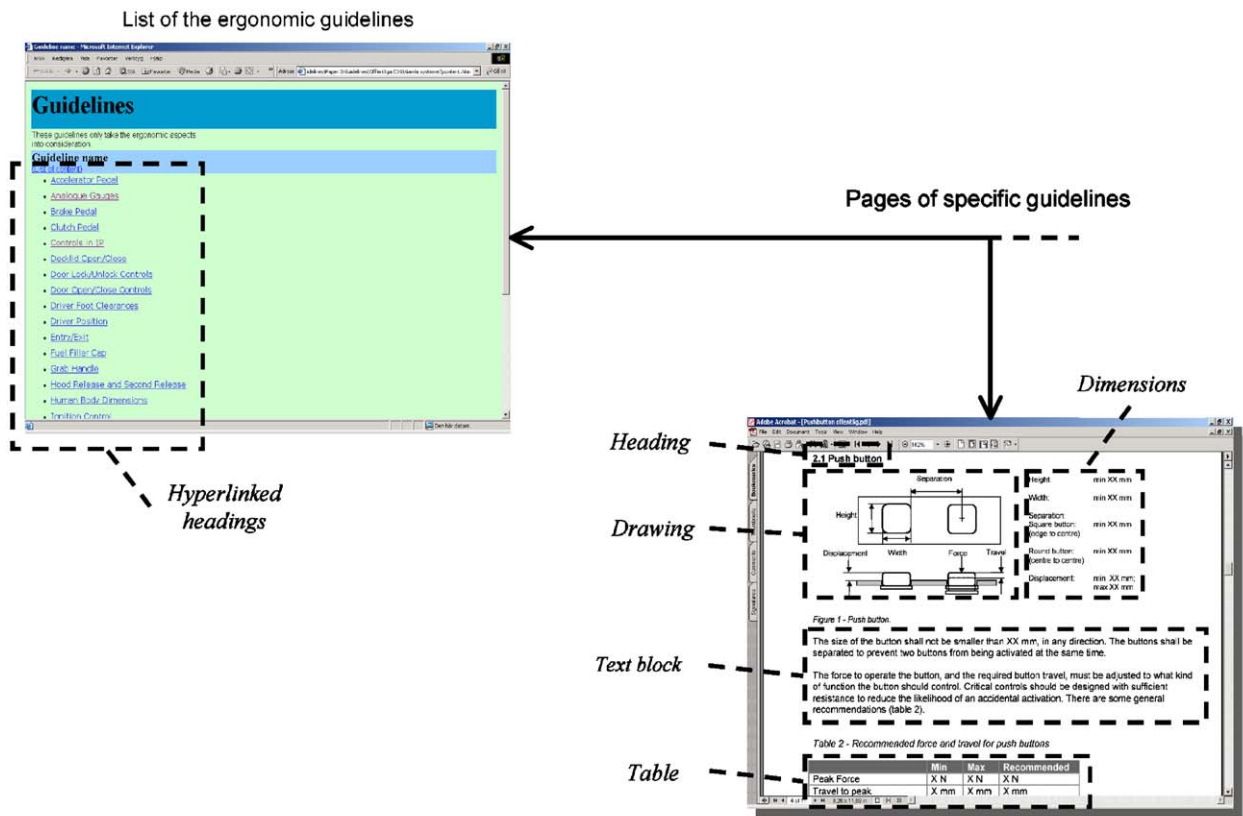


Fig. 1. Two screen dumps of a conventional system showing the traditional path from an alphabetic list of hyperlinked headings (above) to specific ergonomic guidelines (below).

drawings. Specific guideline information, such as the dimensions of a push button, could be presented by a drawing, a table, and a text block on one page, several pages in a sequence, or on separate pages, e.g. pages 8 and 14.

The design engineers received the ergonomic guidelines as paper printouts distributed by the human factors department, and they also had access to the guidelines via the intranet. However, the company wanted to improve the accessibility and presentation of their ergonomic guidelines in order to support the human factors engineers as well as the design engineers when working with ergonomic issues.

### 2.1.2. *Ergonomic guidelines visualized by means of interactive multimedia techniques on an intranet*

Employee participation throughout the whole problem solving process, including planning, testing, evaluation, and implementation of their own work activities has a potential to promote learning, motivation, and company performance (Eklund, 2000). Thus, frequent feedback meetings and discussions were carried out to support set-up designs of prototypes representing different multimedia techniques for visualizing the ergonomic guidelines (interactive/hyperlinked icons, photos, drawings, film clips and animations). These were evaluated by interface and content experts, represented by three researchers working with human computer interaction at Lund University, and three human factors engineers at the Saab Automobile company (Blomé and Odenrick, 2003). Proposed compromises and adjustments were discussed with each of the three human factors engineers at the company, and a complete system visualizing all existing ergonomic guidelines was designed. It was based on the theoretical recommendations presented in the introduction of the present paper as well as user defined requirements specifying the important information that should be highlighted in each ergonomic guideline as well as suggestions as to how that should be done.

Fig. 2 shows the interactive multimedia information system of ergonomic guidelines. It consists of 192 web pages with colored or gray-scaled hyperlinked pictures and animations. The user searches for guidelines by clicking on hyperlinked zones in the pictures, icons or headings. The headings of a group of guidelines or of specific guidelines are integrated with the picture or placed beside if it is hard to find the physical connection, e.g. “Positioning of user functions”. The path to specific guidelines is shown by hyperlinked headings at the top of each page.

Specific guidelines are visualized by pictures or drawings of physical details and human body parts showing scale and/or function. The distinction between a drawing and a picture is somewhat vague. In this study, a drawing is a simplified illustration focusing on dimensional measurements, while a picture is a naturalistic representation using shaded effects (see Figs. 1 and 2). Neither photos nor film clips are used. Instead, throughout the design process of the interactive multimedia system, pictures and animations

are used in some cases to demonstrate function and/or measurements since these were considered to be more obvious, to look better and have no clear connection to specific car models as did photos or film clips. Text and measurements are integrated as much as possible in the pictures according to a recommendation of spatial coordination (Moreno and Mayer, 1999). Hyperlinked icons located at the left side of the page organize different aspects regarding a specific guideline and decrease the need of scrolling. Blocks of text are located to the right or beneath the pictures, thus focusing attention on the pictures (see Fig. 2).

It is possible to make paper printouts of information from the system. However, it is designed for use on an intranet since the path to specific information is accessed by hyperlinks and not by reference to specific page numbers, as was the case in the conventional system. Furthermore, animation effects are lost in the paper printout.

### 2.2. *Subjects*

Five groups of subjects, representing different but relevant characteristics with respect to present and future usage, evaluated the systems. Five persons from each of the following groups evaluated the system, resulting in a total of 25 subjects:

1. Human factors engineers at Saab Automobile representing the persons responsible for and experts on the contents of the guidelines. Four males and one female participated; all were engineers but one also was working at the University and thus not only representing Saab.
2. Engineers and project managers representing users of ergonomic guidelines at Saab Automobile. Two males and three females were randomly selected from a list provided by the human factors department manager. Participation was voluntary, but the subjects received film tickets in appreciation.
3. Lund University researchers – four males and one female – with expertise and knowledge within the field of interface design.
4. Engineering students at Lund University, representing new employees at the company. A student group was asked to participate and was given free film tickets; two males and three females were randomly selected among those who were interested.
5. Industrial design students at Lund University, representing new employees as well as designers at the company. A student group was asked to participate and was given free film tickets; two males and three females were randomly selected among those who were interested.

The subjects of the three first groups were middle-aged and had university degrees; the two student groups were in their twenties.



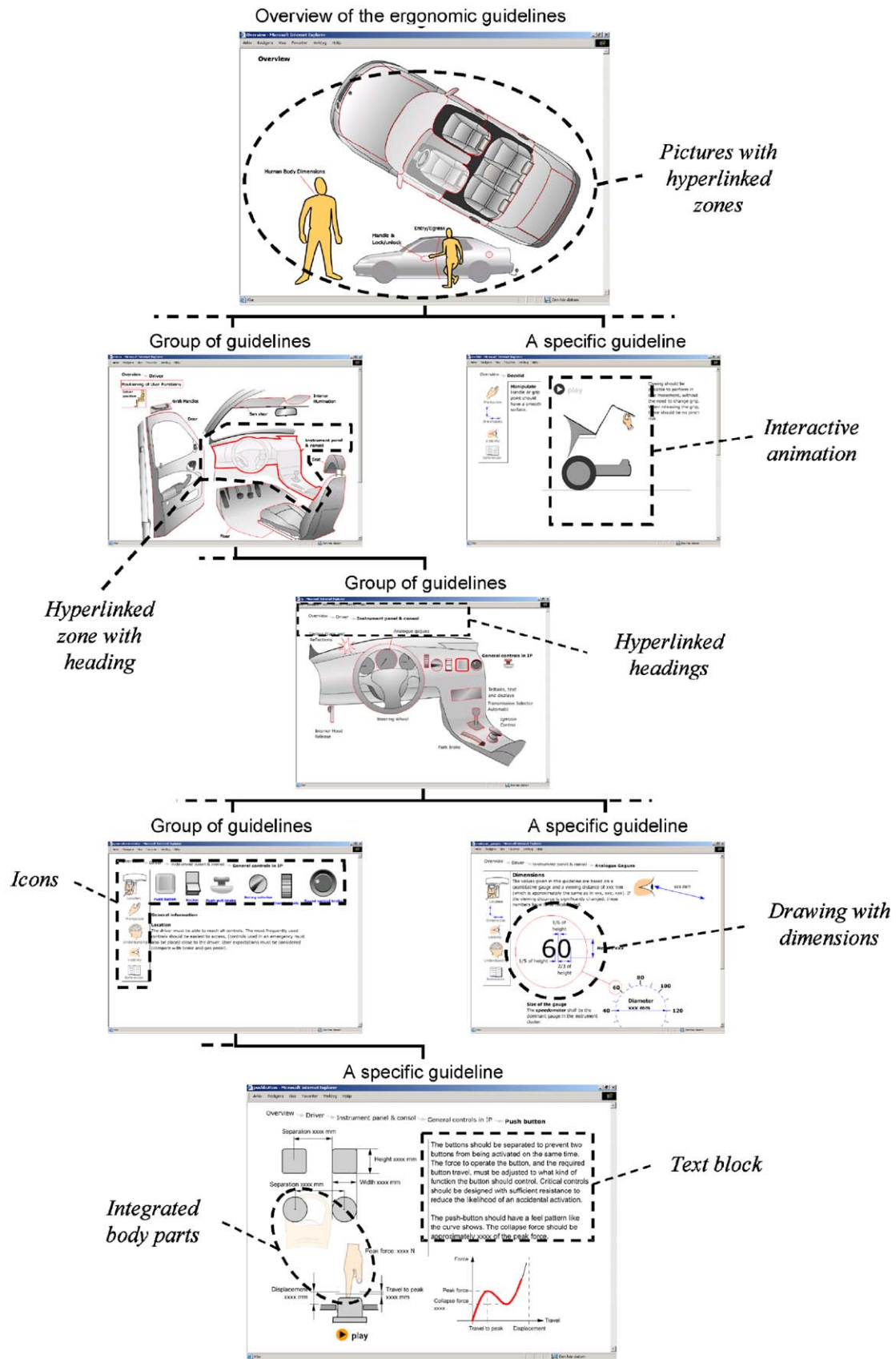


Fig. 2. Seven screen dumps of the interactive multimedia system showing the path to specific ergonomic guidelines.

### 2.3. Procedure

An experiment leader (the first author) introduced each of the subjects on separate occasions to the conventional system and the interactive multimedia system of the ergonomic guidelines using a computer demonstration. After this, the subjects practiced using the systems by solving three tasks in each: the searched for and identified the requested information in three different guidelines while talking aloud (the three guidelines were not used later on in the study by the subjects). Each subject was then assigned to perform a set of ten unpaced tasks as shown in Table 1; first using one system and then the other. The order was balanced, i.e. the first person began with the

interactive multimedia system; and the next person began with the conventional system and so on. Thus the test setup was a mixed design since there were five different groups of subjects, ten different tasks and two different systems (between subjects), all subjects performed all tasks in both systems (within subjects). The task descriptions included keywords that could be found in both systems. Furthermore, each task was orally explained to the subject before starting. The subjects were also asked to think aloud while performing the tasks.

The tasks were designed to explore different visualization approaches in each system. The search path to requested information in the conventional system was presented via a hyperlinked heading on a scrollable page.

Table 1  
Different approaches to visualizing search paths and requested information for each task and system

Task	Visualization		
	System	Search path	Requested information found
1. What body dimensions are there?	Conventional	1 heading, Page 2	List of dimensions followed by drawings with dimensions
	Interactive multimedia	1 zone, 1 heading	Drawings with dimensions
2. How much is the peak force for a push button in the instrument panel? <sup>a</sup>	Conventional	1 heading, Page 4	Table
	Interactive multimedia	3 zones, 1 icon	Integrated in an animation of a finger pressing down a button
3. How many types of handles are there to adjust a seat fore and aft?	Conventional	1 heading, Pages 6–8	Drawings of handle types
	Interactive multimedia	3 zones	Drawings of handle types with a hand showing handling
4. What is the load height for decklid (trunk)?	Conventional	1 heading Page 2	Drawing referring to a table of dimensions
	Interactive multimedia	1 zone, 1 icon	Drawing with integrated dimensions and a hand showing handling
5. Find the positioning areas related to safety belt in back seat.	Conventional	1 heading, Pages 8 & 14	Text block of information and an explanatory drawing on separate page
	Interactive multimedia	1 zone	Interactive picture where a text box emerges when hovering over requested areas
6. What dimensions should the buttons have in the remote control?	Conventional	1 heading, Page 3	Text block
	Interactive multimedia	2 zones, 1 icon	Text block next to a picture
7. What width is recommended for the brake pedal in a car with automatic transmission?	Conventional	1 heading, Page 1	Drawing with integrated dimensions.
	Interactive multimedia	3 zones	Drawing with integrated dimensions
8. What dimensions should the figures in the speedometer have?	Conventional	1 heading, Page 3	Text block
	Interactive multimedia	3 zones, 1 icon	Drawing with integrated dimensions
9. What width should the steering wheel have?	Conventional	1 heading, Page 1	Drawing with integrated dimensions
	Interactive multimedia	3 zones	Drawing with integrated dimensions and a hand showing handling
10. What force is recommended to operate the inside door handle?	Conventional	1 heading, Page 3	Table next to drawing
	Interactive multimedia	3 zones	Drawing with integrated dimensions and a hand showing handling

<sup>a</sup>Task number 2 is illustrated in Figs. 1 and 2 (down to the specific guideline at the bottom).



The actual information was then presented on one page, a series of sequential pages, or on different separate pages. The requested information was visualized with text blocks, tables, and drawings. The search path to requested information in the interactive multimedia system was presented via hyperlinked zones in pictures, icons, and headings. The requested information was visualized with colored drawings, pictures, and animations with integrated dimensions and hands showing handling as indicated in Table 1. The principal differences between the two systems are described by task number 2 in Table 1 and are further illustrated in Figs. 1 and 2 (down to the specific guideline at the bottom).

The subjects performed the tasks by searching for the requested information in the systems and announced when the information was found and understood. The performance was measured with respect to *speed* and *incorrect answers*. The experiment leader measured performance speed in terms of time to accomplish each task. The subjects received help when they were stuck or gave a hesitating answer when performing the tasks. The help was restricted to encouragement to read the tasks once more. Each task was assessed as completed when the subject gave a clear answer and went on to the next task, or finished the test. Behavioral observations as well as oral comments were carefully written down by the experiment leader. The employees at Saab Automobile (group 1 and 2) performed the tasks at the company on a laptop with a 14" screen and mouse, whereas the other groups performed the tasks at the University on a stationary computer with a 15" screen and mouse.

After performing the tasks in the two systems, the subjects evaluated each system by filling in a questionnaire and discussing the answers with the experiment leader, in order to collect data concerning the subjects' attitudes towards the systems. In the questionnaire the subjects were

asked to estimate how easy or hard it was to find and understand the information and to evaluate each system on a five-point scale — very easy, rather easy, neither easy nor hard, rather hard, very hard. The subjects also gave their overall opinion of each system on a five-point scale — very good, rather good, neither good nor bad, rather bad, very bad. Furthermore, the subjects formulated pros and cons for each system and finally explained which system they preferred. The whole procedure including introduction, performing tasks with both systems and filling in the questionnaire, lasted in general about half an hour for each subject.

### 3. Results

#### 3.1. Performance speed and incorrect answers

As shown in Table 2, it took in general less time to perform the tasks (except task number one) with the interactive multimedia system compared to the conventional system. Two way ANOVA with repeated measures showed that significant differences existed between the two systems in three of ten cases,  $p < 0.01$  (task 4);  $p < 0.001$  (task 5);  $p < 0.05$  (task 10);  $N = 25$ .

The participants sometimes received help or gave incorrect answers when performing the tasks. Table 2 indicates that most problems referred to tasks 3 and 5, which also took the longest time to perform. The dispersion for each task was less with the interactive multimedia system (except for task number one). Furthermore, there were no significant differences with respect to performance speed and number of incorrect answers between the five different groups of users, or between male and females.

Table 2

Average time (in s), standard deviation to perform each task, and number of occasions when the 25 participants received help or gave an incorrect answer

Task	Average time (standard deviation)		Help		Incorrect answer	
	Conventional	Interactive multimedia	Conventional	Interactive multimedia	Conventional	Interactive multimedia
1	42.6 (25.0)	43.3 (30.6)	0	0	0	0
2	59.5 (23.6)	49.1 (20.9)	0	0	1	0
3	93.7 (60.1)	86.9 (47.6)	0	1	8	7
4	460.0* (33.6)	38.4* (12.7)	1	0	0	1
5	213** (131)	92.3** (42.8)	5	0	15	10
6	83.4 (65.1)	54.8 (32.8)	0	3	0	0
7	42.0 (30.0)	38.6 (15.2)	0	0	0	0
8	59.8 (42.8)	47.0 (19.2)	1	0	0	0
9	24.7 (18.2)	17.2 (7.51)	1	0	0	0
10	76.0*** (52.4)	45.2*** (46.7)	1	3	1	0
Total	755	513	9	7	25	18

Statistically significant results regarding performance speed are indicated by: \* $p < 0.01$ ; \*\* $p < 0.001$ ; \*\*\* $p < 0.05$ . The data was analyzed by two-way ANOVA with repeated measures.

### 3.2. Attitudes towards the two systems

The attitudes among the subjects towards the two systems were documented by the questionnaire and the behavioral observations. According to the questionnaire, all participants preferred the interactive multimedia system except one of the human factors engineers at Saab Automobile who wanted both systems. The interactive multimedia system was considered to be attractive, enjoyable and interesting to use, whereas the conventional system appeared boring and rigid. Animations and pictures of human body parts made the guidelines of the interactive multimedia system more informative and enjoyable to use.

The behavioral observations revealed that the subjects searched for information by reading text and scrolling up and down pages in the conventional system. In the interactive multimedia system they searched for information by reading pictures and using hyperlinked pictures and icons. The subjects appreciated the use of icons in the interactive multimedia system to organize the information and decrease the need for scrolling. Several subjects expressed positive comments about the interface design and were curious about the information presented in the interactive multimedia system while using it. Some of the subjects also experienced the interactive multimedia system to be much faster than the conventional one, but the difference in speed was less than they expected.

A visit at Saab Automobile 22 months after the study and release of the new system revealed that the new system was still in use, and the human factors department has received positive reactions among users and interested persons throughout the General Motors company group.

## 4. Discussion

### 4.1. Efficiency of the systems in terms of speed and incorrect answers

The results show that the requested information was more rapidly found in the interactive multimedia system of guidelines and also that the tasks were performed more independently and with fewer incorrect answers compared to the conventional system. The results can be explained by the two systems' different visualization approaches to support understanding of *search path*, and of *requested/specific information*.

The conventional system supports a search path that assumes knowledge of relevant keywords that correspond to a hyperlinked heading and further on to specific information; i.e. a verbal system with visual codes according to the dual coding theory of Clark and Paivio (1991). In this study, Relevant keywords were provided in the task descriptions and also explained to the subjects. However, If a user is unfamiliar with the content under the headings, It is likely that it would have been difficult to find the requested information in the conventional system. The interactive multimedia system supports a search path with

more obvious connections to physical details based on keywords as well as recognition of pictorial representations, i.e. an imaginal or nonverbal system according to the dual coding theory. This approach addresses users with different prior knowledge and search strategies, i.e. characteristics of great importance according to Vekiri (2002). However, Task number one was performed slightly slower when using the interactive multimedia system. This could be explained by the use of a heading in the search path of that system but also because the requested information was presented rather fast on the second page in the conventional system. It seems preferable, though, that the search path should be based on recognition of pictorial representations.

The understanding of *requested/specific information* in terms of receiving help and correct answers seems to be greater with the interactive multimedia system compared to the conventional system, although help was offered and incorrect answers were given to tasks in both systems (Table 2). This probably was related to the characteristics of specific guidelines.

Most difficulties were related to tasks three and five in both systems. In task three, the correct answer was “three alternatives”, but some people only noticed two. This was most likely because the alternatives were not separated clearly enough, or because one alternative seemed most unlikely, or because the subjects remembered their answer from the previous system and incorrectly transferred that to the other system since both systems had similar drawings. In task five, the subjects were to find three different positioning areas related to the safety belt. Some subjects only noticed one or two areas, or even some wrong areas. The requested information in the conventional system was to be found on different pages, causing some of the subjects to get stuck and give incorrect answers. These identified difficulties correspond to findings about spatial coordination (Moreno and Mayer, 1999) and conjoint retention (Vekiri, 2002). The guidelines in the interactive multimedia system were easier to find and understand but still some incorrect answers were given, which indicates that the interactive multimedia system needs to be further developed.

Statistically significant results regarding speed were noted for tasks five, four and ten. In task four, the subjects were to find load height for the trunk. In the conventional system, the requested information was presented in a drawing referring to a table with dimensions, whereas the subjects in the interactive multimedia system used a hyperlinked icon labeled “dimensions” to a drawing with integrated dimensions, according to recommendations on spatial coordination (Moreno and Mayer, 1999). In task ten, the subjects were to find the force required to operate the indoor opening handle. In the conventional system, the subjects had to scroll through information about the outdoor opening handle to find the requested information whereas the interactive multimedia system had separate search paths for outdoor and indoor handles from the very

first picture in the system. The approaches in tasks four and ten probably made the users more confident since they found the correct information quickly, which speeded up their performance. This is in line with the studies of visual argument theory carried out by Robinson and Kiewra (1995), since information associated with different regions of a car is best visualized by pictorial maps of a car with hyperlinked zones.

Vekiri (2002) summarizes a number of studies by concluding that using appropriate visualization decreases the cognitive load which would result in a more effective processing and learning of information, measured by retention tests and ability to transfer the information to new situations. In accordance with this conclusion, the comparison of the two systems in this study, representing different visualization approaches, resulted in increased efficiency in the interactive multimedia system of ergonomic guidelines in terms of performance speed, somewhat decreased need for help, and fewer incorrect answers. Furthermore, lower standard deviations for performance speed in the interactive multimedia system indicate a more suitable approach to users with different characteristics compared to the conventional system. Thus, the interactive multimedia system represents a more appropriate visualization approach to support the *search path* and understanding of *requested/specific information* in ergonomic guidelines than the conventional system.

#### 4.2. Attitudes towards the two systems

The results show a more positive attitude towards the interactive multimedia system compared to the conventional one, which is of great importance for the usability of an information system according to the REAL analysis (Löwgren, 1993). Some people also felt that it was faster (than it actually was) to use the interactive multimedia system compared to the conventional one. Two explanations could be the design process, as well as the design itself of the new system. The evaluation can be regarded as a part of the design process, letting the users participate and affect the design of the new system of ergonomic guidelines. Besides suitable solutions, the participatory approach resulted in positive attitudes towards the interactive multimedia system, which corresponds to findings about participatory ergonomics (Wilson and Haines, 1997). The other explanation could be that the design itself of the interactive multimedia system encouraged users to explore the guidelines by interactive colorful drawings with hyperlinks and animations providing instant feedback, compared to the conventional system's more monotonous approach. The characteristics of the interactive multimedia system with interactive drawings and animations are very similar to those of educational multimedia products (Macaulay, 1996; Kunskaforlaget, 1999). These products inspired the design process of the interactive multimedia system but with a moderate amount of multimedia effects, which according to Schnotz and Lowe (2003) can decrease

the possibilities for learning if used too extensively. In this study the appropriate amount of animation was somewhat ensured by the participative design approach of the interactive multimedia system.

A positive attitude is likely to increase the users' attention, which according to the active learning assumption would support a mental integration of information with earlier knowledge (Mayer, 2003). Thus, the interactive multimedia system provides better conditions for the users to gain a positive attitude towards learning about ergonomic guidelines than the conventional system. The results also show that the findings and approaches concerning visualization within different areas, such as participatory design and educational psychology, were applicable to visualization of ergonomic guidelines on an intranet for different users within the vehicle industry.

The fact that the new system was still in use 22 months after the study was carried out, and has gained positive reactions throughout the company group, indicates a successful methodical approach of the study and the system itself.

#### 5. Conclusions

Summing up the discussion with respect to the purpose of this paper, it can be concluded that:

- A system of ergonomic guidelines based on interactive drawings, pictures, and animations supported by text is generally faster and more enjoyable to use than a conventional system based on text supported by drawings.
- It is preferable to visualize ergonomic guidelines with pictures of different views of a car with groups of guidelines and specific guidelines connected to hyperlinked zones. Furthermore, a specific ergonomic guideline should focus on drawings where dimensions and body parts are integrated with physical details showing dimensional relations and how the details are to be used. An animation makes it easier to understand the use of details and dimensional relations and also makes the presentations more enjoyable to use.
- It is a successful approach to visualize an interactive multimedia system of ergonomic guidelines based on findings in web design and educational multimedia with a participative design process.

By visualizing ergonomic guidelines according to the principles presented in this case study, users with different backgrounds will probably find the information more interesting, easy to locate and interpret than a traditional visualization of ergonomic guidelines with a list of headings and text-based documents in a report form. An interesting question for future research is to explore how a system of guidelines according to recommended principles should be maintained to continuously develop and document knowledge of ergonomic issues.

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