Research Article

Information Design for Small Screens: Toward Smart Glass Use in Guidance for Industrial Maintenance

—HANNA HEINONEN, SANNI SILTANEN, AND PETRI AHOLA

***Abstract*—Background:** *Smart glasses and other extended reality (XR) solutions provide new ways of utilizing technical documentation with hands-busy tasks in the field. Scaling up the use of XR solutions in industry has been difficult due to the manual authoring of content for each device and task. Therefore, authoring solutions and information design methods need to be developed to scale content automatically to different devices and applications.* **Literature review:** *Related work includes smart glasses and industrial maintenance work, categorization based on users' skill levels, and standardized guidelines in information design.* **Research questions:** *1. How should information content be designed and created to support use in smart glasses and other small-screen devices in addition to existing delivery channels? 2. How can the same information content be utilized to deliver relevant content to users based on their skill levels? 3. Are the users of technical instructions ready to accept smart glasses and XR as a delivery channel?* **Methodology:** *We describe a study that focused on designing maintenance instructions for small screens. The information was authored in DITA XML format, and a smart glass application was used in user tests to evaluate the delivery and usability of the information. We used thinking aloud and participant observation as well as questionnaires to collect data.* **Results and discussion:** *The chosen information design methods successfully compressed technical information, and automatic filtering of content supported different use cases. Participants were enthusiastic about the use of smart glasses, and the instructions helped in performing tasks.* **Conclusions:** *Information designed with the user-centered approach of minimalism works best with instructions on small screens, and filtering information using DITA XML elements is an efficient way to scale information for different user needs.*

Index Terms*—Darwin Information Typing Architecture (DITA), industrial maintenance, smart glasses, structured authoring, extended reality (XR).*

Traditionally, maintenance instructions have been delivered on paper copies, but paper delivery has proven problematic for many reasons. For example, an outdated copy of instructions might be accidentally used, and there are costs involved with printing. The trend has been, therefore, to move the delivery of information to electronic print formats—i.e., PDFs and more recently online portals. However, as industrial maintenance is often characterized by tasks that require the use of personal protective equipment while keeping the technician's hands busy holding equipment parts and tools, it is often difficult to access instructions while performing a task. Therefore, to solve this issue, the focus has turned beyond PDFs and online portals to new delivery methods, especially to extended reality (XR) solutions.

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Extended reality is an umbrella term for technologies combining virtual and real elements. There are several levels of immersivity among XR applications, varying from total digital virtual reality (VR) environments, through mixed reality (MR), to augmented reality (AR), where the virtual elements are added on top of the user's view of reality [1]. In industry, VR is used, for example, in training and design reviews [2], and MR is used for many visualization purposes [3]. AR, especially when applied with smart glasses, is used in industrial settings for workflow guidance, reporting, and remote assistance [4], [5]. Solutions where information is displayed on smart glasses are sometimes also referred to as informed reality or assisted reality.

In industrial maintenance, it is not feasible in terms of resources to tailor instructions manually for different outputs and devices. Therefore, it is essential that the technical instructions displayed on XR devices be automatically retrieved from a company's repository. As demonstrated by Siltanen and Heinonen, Darwin Information Typing Architecture (DITA) XML is a good candidate for the creation of content for XR applications [6]. DITA is the technical communication standard for

Practitioner Takeaway

- Instructions displayed on smart glasses help users perform tasks in industrial maintenance, and attitudes towards using smart glasses are positive.
- Well-designed technical information can be automatically used and delivered for several use cases and in several end devices.
- Information designed with the user-centered approach of minimalism works best with instructions on small screens, and filtering information using DITA XML elements is an efficient way to scale information for different user needs.

Fig. 1. Test participants performing maintenance tasks during user tests. The personal protective equipment (hardhat, safety shoes, and cut-resistant gloves) is the same that is required for field operations.

structured writing, and it defines three main topic types: concept (what something is like or how it works), task (how something is done), and reference (information users might need when performing a task) [7]. A repository is used to store the topics, which can then be reused across publications and in different delivery channels.

However, even though we are nearing the era when XR solutions could be utilized on a wider scale in industrial maintenance, very little has been done to create any guidelines for the use of the new media and technologies in the field that specializes in designing and creating technical instructions and guidance, technical communication [8]. Even though DITA offers the technical capability to produce content for XR solutions, the focus needs to be put on designing the content so that it scales according to the media and users' needs. It is also of utmost importance that these concepts are developed and tested in real industry settings, taking into account the actual work environment and the challenges that arise from it. For example, the mandatory use of personal protective equipment (see Fig. 1) in many industrial roles has a substantial effect on how different devices and solutions can be utilized in the field [9]. For example, if safety glasses are required, AR glasses need to be compatible with them to meet the safety standards.

KONE is a global leader in the elevator and escalator industry [10]. It operates in more than 60 countries with approximately 30,000 field employees with varied levels of expertise. As new products are introduced often, even experienced field workers need detailed instructions for them. KONE publishes hundreds of new or revised instructions each year, and, therefore, single sourcing and reuse between information products and different outputs is essential. KONE has also been actively looking into novel ways of delivering technical information to field workers.

The aim of this research is to better understand how technical information content should be designed and created to support use in XR and other small-screen devices in addition to the existing delivery channels. Many industrial companies already produce instructions in DITA XML format that can be transformed into PDF or HTML formats or published to a web service for dynamic delivery to applications. However, the same content needs to be adapted to fit better in small display devices and to automatically filter content to support XR use cases. This study is a step toward creating guidelines for the design of content for omnichannel delivery, including smart glasses.

Next, we review the related work and present our research questions. Then, we explain the research methodology and the test arrangements. Finally, we describe the results and discuss future directions, and end the article with conclusions.

Literature Review

This exploratory study brings together research related to smart glasses and industrial maintenance work, categorization of users based on their skills levels, and standardized guidelines in information design. Smart glass use is a prominent area of research in industrial maintenance, and combined with information design, it offers a new way of delivering maintenance instructions to field workers. When delivering instructions to the limited space available on small screens, it is very important that the information be readable and fits the screen. Therefore, we also wanted to look into categorization of users' skills levels as a way of delivering the correct amount of information.

Smart Glasses and Hands-Busy Work in Industrial Maintenance Modern maintenance work is no longer only about using physical tools, such as screwdrivers, and getting measurements and values on physical gauges. Increasingly, technicians need to interact with digital information and information systems. Equipment information has moved to Internet of Things clouds, and technicians need to check parameters, equipment performance indicators, and measurement readings from information systems. Instructions are no longer only paper manuals but are stored in electronic format and accessed with mobile devices.

In many cases, industrial maintenance tasks require hands-busy actions and, in some cases, both hands are required most of the time [11]. Considering that the technician also needs to wear gloves that can be dirty and greasy, it is clear that a mobile phone with a touch screen user interface is not the optimal device to access information systems in these situations. For these use cases, smart glasses provide a potential solution. User interaction challenges and solutions in maintenance are very similar to some healthcare situations where both hands are needed, the hands might be dirty, and special attention needs to be paid to maintaining a sterile field. In healthcare, the use of smart glasses has also been studied to overcome these challenges [12].

Klinker et al. presented more than 20 use cases for smart glasses in maintenance [13]. One of the prominent use cases is providing workflow information for maintenance technicians. Industrial companies have experimented with smart glasses and, in several use cases, maintenance instructions are displayed using smart glasses [4], [5]. Studies show that users are able to perform faster and reduce error rates with such systems [14]–[16]. In addition, users feel more competent and satisfied [17], [18]. Adequate instructions provided with smart glasses instantly enhance the users' skills. Thus, technicians with different competence levels are able to complete maintenance tasks successfully.

Smart glass use has been often studied and tested in single-purpose use, and content has been tailor-made for each use case, a solution that is costly. Since smart glasses are still quite costly as well, especially those that meet industrial standards, the adaptation of smart glasses to industrial maintenance has been low despite the obvious benefits. However, if existing technical instructions already used for other formats can be reused for smart glasses and if the delivery is automated, the number of use cases increases drastically. Furthermore, when the work processes and practices are designed to support multipurpose use, the return on investment increases considerably. For example, smart glasses can be used to get remote assistance, read technical information, and utilize AR guidance (see, for example, SightCall [19]).

Expert–Novice People working in the field have different skill levels, varying from trainees to experts with lifelong experience. Experienced maintenance technicians know how to perform highly complex maintenance procedures [20]. In many cases, the knowledge they possess is tacit or tribal in nature. At the other end of the continuum, novice users are anxious about making mistakes and want to get started quickly with the tasks at hand [11]. Advanced users may know and remember the task sequence in general and need only to check some details. They prefer to have detailed guidance only when performing tasks that occur rarely or that are new to them [21]. Novice users, on the other hand, need more generic guidance to be able to complete the task. In short, different types of users with varying skill levels have different requirements for technical information [22].

The classification of users into categories based on their skill levels is an established concept in technical communication. Hackos, for example, classifies users into expert performers, competent performers, advanced beginners, and novices [23]. These user profiles are used when creating and delivering content to meet the needs and demands of a specific target group. A user can be an expert for some tasks and novice for other tasks. Thus, the level of expertise and the need for guidance depend on the task at hand. Funk et al. use adaptive assistance for field workers with three different expertise levels–novice, advanced, and expert–to give each group a different level of guidance [24]. A common practice with DITA XML is that the filtering is done with conditions (audience = expert/novice), which requires that each sentence or segment in the DITA XML source be defined for expert-level users, novice-level users, or both.

Traditionally, many maintenance tasks have been standardized. For example, a certain set of preventive maintenance actions is performed at a set interval, and by working with the same equipment for years, the technician learns the tasks. However, the ongoing fourth industrial revolution is also changing the way maintenance work is performed. The Internet of Things, connectivity, and digitalization are transforming even the more traditional heavy industries, giving rise to concepts such as remote and condition-based maintenance. In these settings, the tasks vary from one piece of equipment and day to another, the maintenance technicians have a unique set of tasks to be performed at each maintenance visit, and it is no longer possible even for the experienced maintenance technician to know the tasks related to a certain preventive maintenance visit, for example. Therefore, there is an increased need for guidance even for the experts.

Standardized Guidelines in Information Design
Company style guides are created to provide consistency within each technical instruction and a larger set. In addition to setting standards for writing and formatting, style guides enforce guidelines for information design. The foundations for company guidelines lay in technical communication literature, where, for example, it is recommended that the number of steps in procedures be restricted to a maximum of nine [25], or that information is chunked into meaningful pieces to help readers make lengthy text more manageable to reduce the cognitive load [26]–[29]. These guidelines are based on an established theory in psychology: the magical number seven, plus or minus two. According to this theory, most people are capable of storing between five to nine items in their short-term memory [30]. In addition to technical communication, this theory has been applied to several aspects of daily life, for example, the length of telephone numbers, or recommendations for the maximum numbers of points in oral presentations [31].

Even though these guidelines are widely used in information design, it has also been argued that users of technical instructions do not have to memorize the steps of a procedure, but they typically read the steps one by one as they are performing the related tasks [25]. But with hands-busy maintenance procedures, it is not always possible to flip the pages of a paper manual or scroll down the screen to proceed one step at a time, and the users are forced to memorize a certain number of steps or chunks. Therefore, it has been safer to refrain from writing long procedures and keep them as short as possible or meaningfully chunked, even if that ends up fragmenting the overall task.

RESEARCH QUESTIONS

As the literature is lacking in guidelines for small-screen information design, we wanted to validate the type of information design principles that should be used for small screens where the instructions are available while the user is performing tasks. Therefore, we designed our study to explore whether the established guidelines in technical communication apply when designing information specifically for small screens. We also experimented with the standard semantic structure of DITA XML to see whether it can be used to filter content based on the user's expertise level. Furthermore, since the use of smart glasses to

TABLE I
SELECTED TASKS AND RELATED DEVICES

Task Name	Device Used	Task Description
Install motion sensor cable	Connectivity device	Performed on the elevator car roof. The user routes the motion sensor cable through the roof into the elevator car.
Power-up Connection	Connectivity device	Performed on the elevator car roof. The user connects the motion sensor cable to a connectivity device, switches on the device, and checks that it turns on.
Replace MediaPlayer	Content streaming device	Performed in a residential building lobby. The user replaces a broken content streaming device behind a TV.

TABLE II
SELECTED INFORMATION DESIGN METHODS

Method	Description
Conventional	Based on original instructions available for the tasks. No redesign of content, but due to limitations of the test device used (the screen size and features of the application), some minor, mostly layout modifications were needed for both text and graphics. (Fig. 4, left)
Visual manual	Based on the visual manual theory of Gattullo et al. [32]. The aim is to replace text with graphics, symbols, and icons. (Fig. 4, center)
Minimalist	Based on the minimalism heuristics of van der Meij and Carroll [33]. With minimalism, be aware of what to include, but also what not include, using a user-centered approach. In practice, provide only the information that users need to perform a specific task, and omit unnecessary details. Error prevention information is also included to aid the user. (Fig. 4, right)

deliver technical instructions is new, we also wanted to study users' attitudes toward this new delivery channel.

Therefore, our research was motivated by three key research questions.

RQ1. How should information content be designed and created to support use in smart glasses and other small-screen devices in addition to existing delivery channels?

RQ2. How can the same information content be utilized to deliver relevant content to users based on their skill levels?

RQ3. Are the users of technical instructions ready to accept smart glasses and XR as a delivery channel?

RESEARCH METHODOLOGY

Test Material Design Authentic KONE elevator maintenance and installation tasks were utilized in the study. We selected tasks for which the test participants would have to follow the instructions and would not know or guess the steps involved, but which would be simple enough to be completed in the chosen test setup and within a set timeframe. Three different sets of task instructions were created for each of the selected tasks. The selected tasks are presented in Table I and the selected information design methods in Table II.

The conventional version was chosen for this study as the baseline. Earlier research had indicated that traditional technical content is too long for small-screen delivery [6], so we used this as the reference version for the study.

Second, a visual manual version was chosen because the underlying theory considers the whole documentation production process, including the conversion of existing documents to AR (see Fig. 2). It is designed both to convert existing paper-oriented instructions to augmented reality instructions and to write new AR instructions from scratch [32], [34], [35]. The theory promotes replacing existing text with graphics, symbols, and

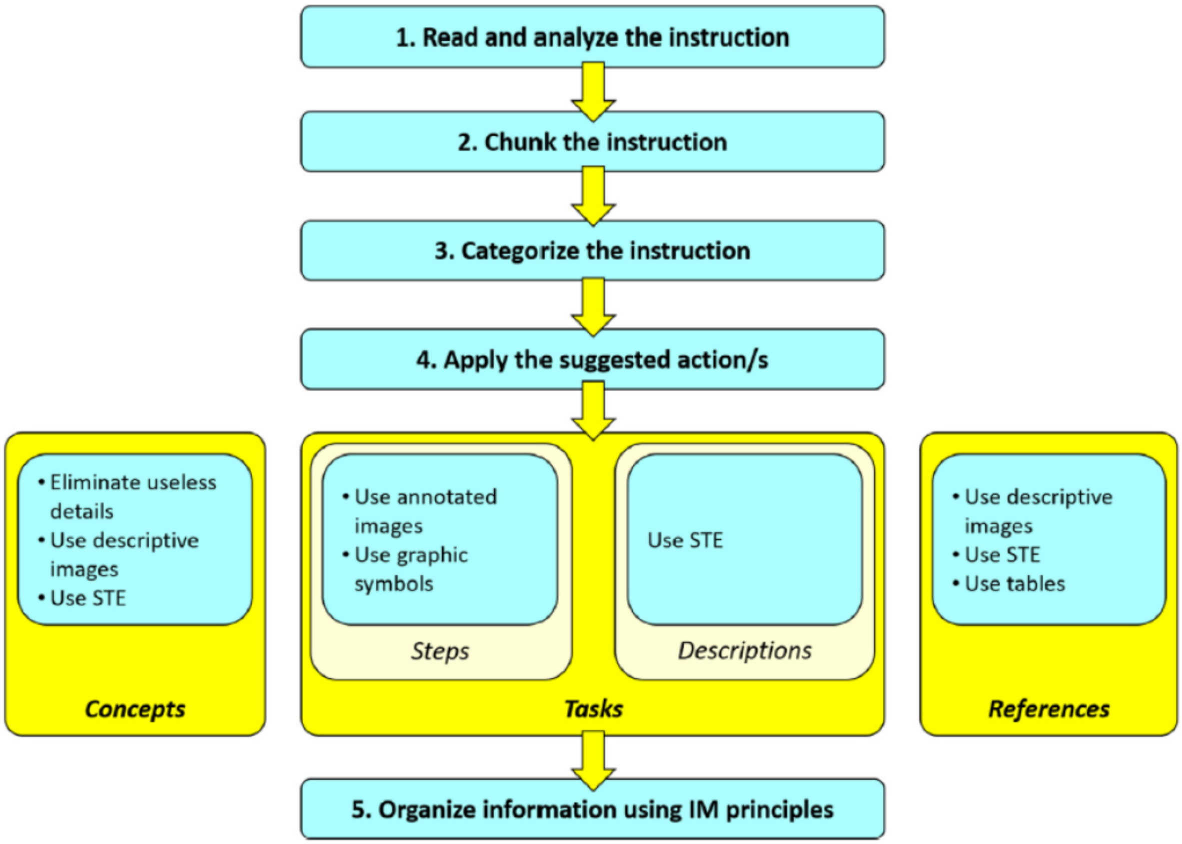

Fig. 2. Main conversion steps of visual manual theory (STE = Simplified Technical English, IM = Information Mapping) [32].

icons [32]. For many companies, legacy documentation must be utilized in one way or another to avoid losing their investment in it, even to the extent that the legacy and any new designs must be synchronized, since both are required by the company's field operations. As the amount of text in this version is limited, it is also cost-effective in terms of translation [34]. According to Gattullo et al., even though modern research acknowledges that more visual instructions are aligned with augmented reality (AR) and Industry 4.0 purposes, there is a lack of specific guidelines to convert existing instructions to visual manuals [32]. Most related research—for example, Knopfle et al. [36], Stock et al. [37], Engelke [38], Gimeno et al. [39], and Erkoyuncu et al. [40]—primarily discusses creating new content. Therefore, existing documentation does not reach technicians.

The third approach, using the minimalism heuristics of van der Meij and Carroll [33], was chosen because it is user-centric. It does not rely on conversion theory as such, but design principles for any technical communication content. In our test material design, the minimalism heuristics were used as a more researched counterpart to the visual manual theory. The minimalism heuristics work well on a small screen because unnecessary descriptive and transitional text is omitted.

The minimalism heuristics stress that one does not write instructions describing the full system, but includes only the steps that a user needs to perform his or her tasks. The user's goals and the tasks themselves must be known before writing the instructions. Also, error prevention information (notes, warnings) is added to save the user's time.

All the test content was authored in English in DITA XML format. DITA XML is also the standard suggested by Gattullo et al. for their visual manual theory [32]. Fig. 3 shows one of the original tasks, rendered in PDF format.

The original task explains why the cable has to be secured with cable ties, but for the target-audience, the trained maintenance technician, there is no need to include this information. As the conventional version was based on the wording of the original task, the explanation was left in that

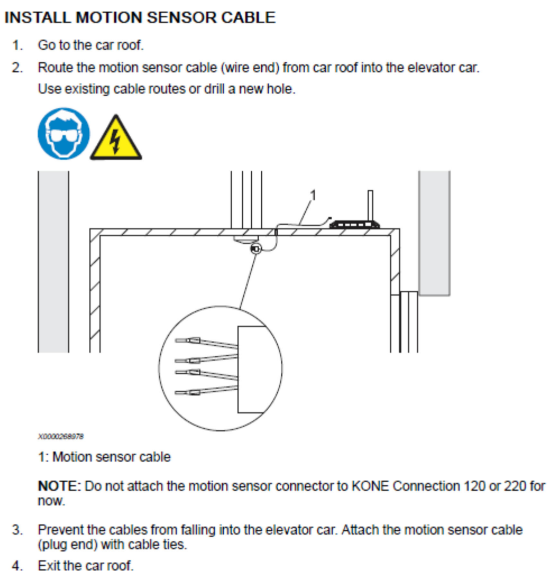

Fig. 3. Original version of the task “Install motion sensor cable.”

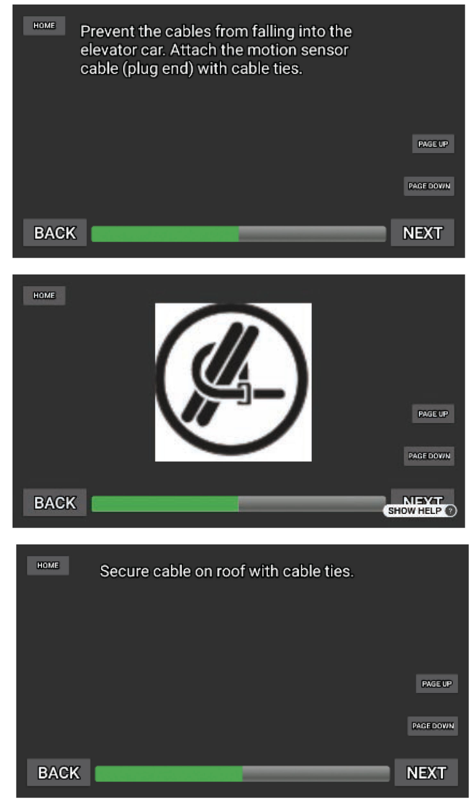

Fig. 4. Three versions of the same step in the smart glass application: conventional (left), visual manual (middle), and minimalist (right).

version. For the visual manual version, we created an action symbol to indicate securing the cable and replaced the textual instruction with the symbol. For the minimalist version, we removed most of the descriptive text because, based on a target-audience analysis, we concluded that the target audience does not need it. Fig. 4 illustrates the results of step 3 of the original task with different methods. Test material design is described in detail in a master’s thesis by Petri Ahola [41].

Test Application To test the concepts, a simple test application was developed for RealWear HMT-1 (see Fig. 5). We selected Realwear HMT-1 as the end device because it has a quite reliable voice user interface that facilitates hands-busy types of maintenance tasks. Furthermore, HMT-1 is compatible with a hardhat and a helmet, and it is a good representative of smart glasses suitable for industrial use.

In the test application, we targeted two issues:

- Focused information for experts, showing only certain parts of the existing content to the users—checklist type of use
- Information flow and the way the information is displayed on the screen

We wanted to show checklist type of information to people who are already familiar with basic maintenance tasks—that is, only the information that the expert-lever user needs. In this research, we use the term *checklist* to indicate a simple list of items that you have to inspect or check, or simple steps that you have to perform, without lengthy explanations or descriptions of the steps. The intention was to tackle the problem that if we show all the information that a novice needs, the experts have problems finding the information that they need as the details are buried in the wealth of information. With our checklist, experts would have a reminder of what to check or do, but they could use their own expertise to perform the actual tasks.

We achieved the checklist by defining certain DITA XML elements that would be displayed; the rest would be ignored by the application (see Fig. 6). As DITA XML is based on semantic tagging of content [42], we could rely on the fact that certain elements would contain the information that we wanted to show. The approach that we utilized enables the reuse of information, and no hand-tailored expert files are needed. In other words, the same XML file can be used to resolve the full content, including the novice-level information, in another application or output. Traditionally, the expert-novice distinction is achieved with the use of conditions and conditional processing, but we wanted to

Fig. 5. RealWear HMT-1 with a hardhat.

```xml
<title>Install motion sensor cable</title>
<taskbody>
<prereq>You must have a new replacement cable before starting this task.</prereq>
<steps>
<step><cmd>Go to the elevator car roof.</cmd>
<info>Follow safe procedures for going to the car roof. Make sure you have familiarized yourself with all the needed safety instrutions.
<image href="W13.svg"></image></info>
</step>
<step><cmd>Route the motion sensor cable (wire end) from car roof into the elevator car.<image href="image1.png" placement="inline"></image></cmd>
<info>Pay attention to the ends of the cable and route it in the correct way.</info>
<stepresult>The cable is now routed properly.</stepresult>
</step>
<step><cmd>Prevent the cables from falling into the elevator car.</cmd>
<info><note>Watch out for other people working with the equipment. Always follow safe procedures when working on the elevator car roof.</note></info>
</step>
<step><cmd>Attach the motion sensor cable with cable ties.<image href="image2.png" placement="inline"></image></cmd>
<info>Make sure that the cable tie is firmly attached. Cut off extra lenght from the cable tie.</info></step>
<step><cmd>Exit the car roof.</cmd>
<info>Follow safe procedures for exiting the car roof. Make sure you have familiarized yourself with all the needed safety instrutions.
<image href="W13.svg"></image></info>
</step>
<step><cmd>Finalize maintenance visit.</cmd>
<info>Remove all the tools and waste material from the work site. Dispose of any waste according to local regulations.
<image href="image3.png" placement="break"></image></info></step>
</steps>
<result>You have now installed the motion sensor cable.</result>
</taskbody>
```

Fig. 6. Example of XML elements displayed and ignored by the application. Displayed elements are highlighted in the figure; all other fields are omitted.

explore ways to utilize the semantic structure of DITA XML and avoid adding conditioning to multiple parts of each topic. This approach saves time in the authoring phase as the conditions would always have to be manually assigned for each element.

Interface design for the test application was not in the focus of our study. However, some simple interactions were developed for the test application. The application was designed to show one step at a time, progressing with “next” and “back” voice commands. On each screen, a progress bar was shown that indicated the progression of the total maintenance task. The aim was to avoid or minimize the need for scrolling that is a usability problem on small screens, especially with voice commands [6]. In case the content did not fit on the screen, “page up” and “page down” commands could be used to access it. For an example of a UI screen, see Fig. 7.

We produced the XML files with XML authoring tools, and they had exactly the same structure as

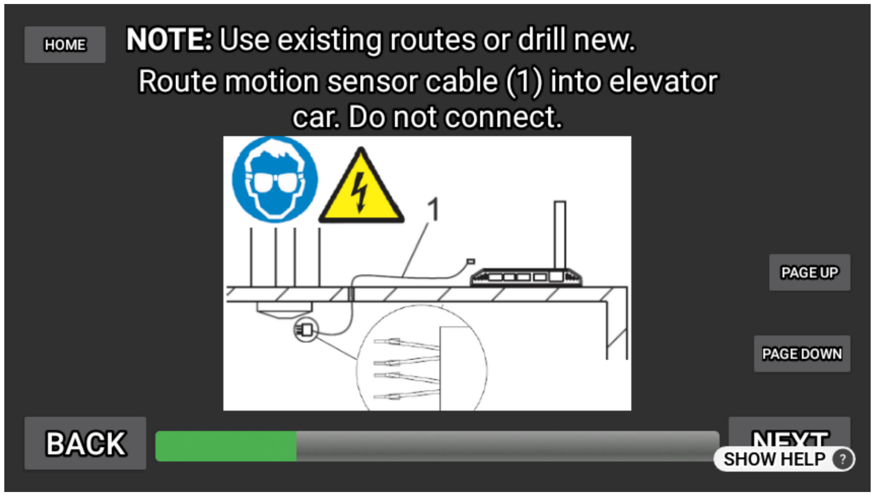

Fig. 7. Application UI showing one step, voice-activated action buttons, and the progress bar.

any XML files utilized in the company's technical instructions. For this study, the files were saved locally in the HMT-1. This allowed for the quick iteration of the different test files in the development phase as no publishing to the web service was needed. The tasks were accessible from a main menu in the application. The menu was created dynamically from an XML file containing references to the XML task files.

Participants A total of 21 test participants from the elevator company participated in the user tests and evaluated the different instructions (18 male, 3 female). Most participants fell into the 30–39 ($N=8$) or 50–59 ($N=7$) age groups, and the rest were from 40–49 ($N=4$), 20–29 ($N=1$), or > 59 ($N=1$) age groups. All the participants were native Finnish speakers but had at least a working knowledge of English.

Six of the participants had worked in a field position or were very experienced, two were familiar with the field environment, and six were somewhat familiar with the field environment. The rest of the participants had very limited experience of the field environment ($N=2$) or no experience ($N=6$). However, the participants that had limited or no personal experience of the field environment were working with field documentation, maintenance development, or related roles, and all but three can be considered expert-level users of maintenance instructions.

Most of the participants had experience in industrial maintenance ($N=10$) or technical documentation ($N=5$). Participants also had a background in engineering ($N=4$), installation ($N=3$), or IT ($N=3$). One participant was an elevator maintenance student.

Test Methods We used a combination of conventional qualitative and participatory methods: thinking aloud, participant observation, and questionnaires. These methods are known to reveal the behavior and perception of users [43]. Due to the small size of our test group, the statistical results are only indicative. Instead of relying on statistical inference, the quantitative results of the questionnaire are interpreted through experts' remarks and verbal observations. This research is at the conceptual phase, and qualitative methods support this phase best.

First, we observed participants during the test. The participants were also instructed to think aloud while performing the task. They were instructed to explain what they were doing, what they liked and disliked, what they did not understand, and voice it when having a doubt. The sessions were also video recorded so that we could go back and check a detail if needed.

The participants were also asked to complete a questionnaire to find out attitudes, preferences, and opinions regarding each method, and to compare the methods. In addition to user background questions, the questionnaire contained 7-point Likert-scale questions and free-form questions. In addition, one part of the questionnaire included 7-point Likert-scale questions related to the use of smart glasses.

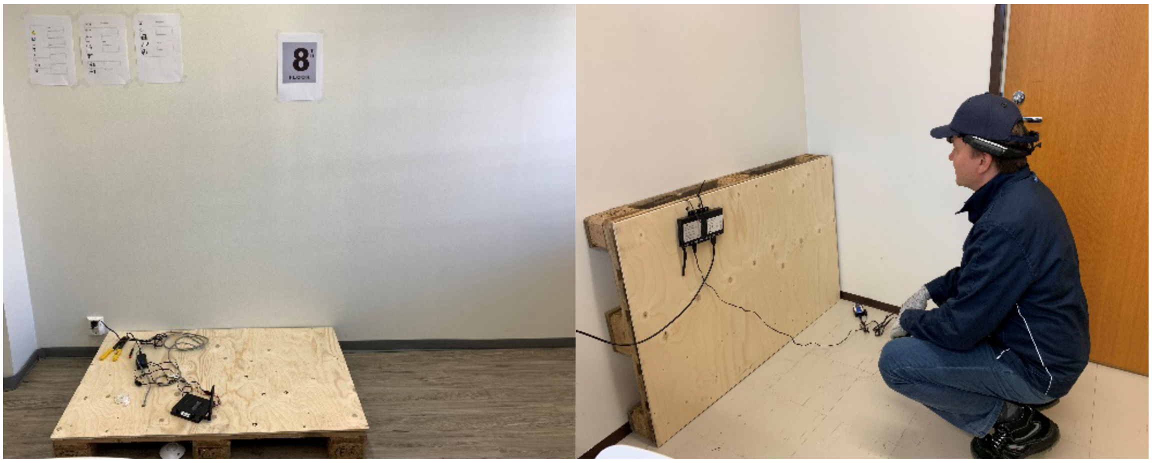

Fig. 8. Test setup: Elevator shaft and car roof simulation (left); lobby (right).

The collected data were recorded and stored in a company SharePoint database. Data storage and removal observed company guidelines and policies as described on the user consent forms. The authors grouped similar items together and analyzed the data.

Our study did not involve ethical issues that would require ethical review according to the local regulations. Therefore, the study was exempt from Institutional Review Board (IRB) review.

Test Setup Two test tasks were meant to be performed on an elevator car roof. Because the elevator car is located inside an elevator shaft, and only qualified personnel are allowed to enter the shaft, in our user study, the shaft and the elevator car roof were simulated with a pallet with a fixed plywood top in a meeting room. The test equipment was located on the pallet (see Fig. 8). This simulation allowed us to avoid any safety-related issues that might arise from working on actual equipment, yet the task mimicked performing the task in a real environment. The setup was explained to the test participants, and during the tests, when requested to enter the car roof, they stepped on the pallet. The third task was meant to be performed in a building lobby. We simulated the lobby in the same meeting room, using a monitor as the TV screen. Another pallet with plywood was used to simulate the fixing of the equipment behind the TV.

Two identical rooms with identical test setups were used in the user tests. A 2-hour timeslot was reserved for each testing session.

The comprehension of symbols was not within the scope of this study; therefore, a list of symbols used in the instructions was available for the participants during the test (see Fig. 9). Participants were encouraged to check the meaning of any symbols during the study and ask for help if they could not understand the meaning of symbols.

Each test participant conducted a series of three tasks. For each of the three tasks, we had three different versions of the instructions created according to the selected compression methods: conventional, minimalist, and visual manual. Therefore, a total of nine different instruction sets were used in the tests. We varied both the order of tasks and the order of compression methods, and different tasks were tested with different methods by different people. Each test participant used and evaluated all three of the methods during the user tests.

User Test Session Flow The user test sessions followed a predefined flow. First, as most of the participants came to the user tests directly from other work duties, they were offered some refreshments and asked to relax and orient to the user test. While each participant was having refreshments, we explained the scope and purpose of the user test, asked for research consent, and requested permission to record the session and take photographs.

Second, we introduced the test setups, devices, and tools used in the test (see Fig. 10). We explained how smart glasses function and fitted the display for the participant. In addition, we went through the symbols and their “cheat sheets” on the wall.

Third, we emphasized that we were testing technology and information compression methods, not the participant. We explained that it is

Fig. 9. Test participant examining the list of symbols used with the visual manual method.

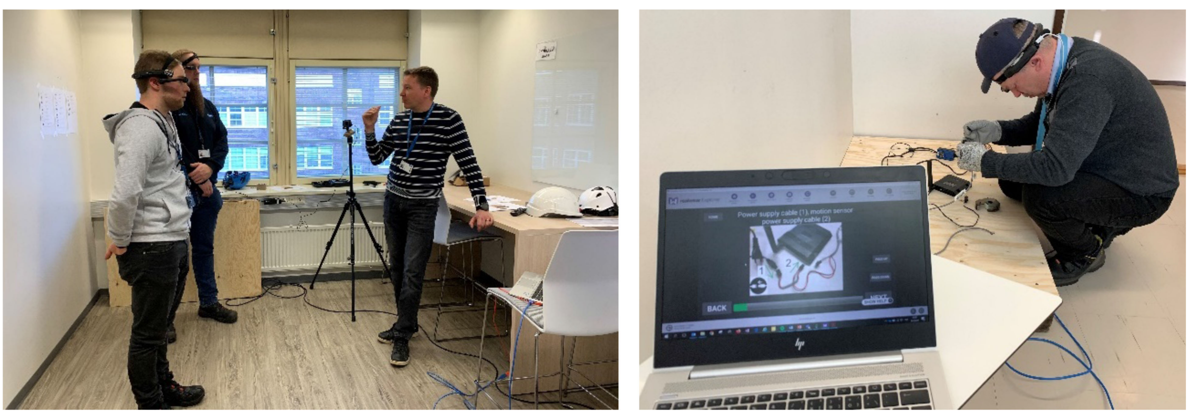

Fig. 10. Test setup and tasks being explained to participants (left). User test in progress (right). The smart glasses were connected to a PC so that we were able to follow what participants saw on the glasses.

important that the participants try not to please us, but openly express their thoughts and concerns. The participants were asked to think aloud, describe their actions, and express all the thoughts that they have regarding the tasks and the setup. They were also asked to think aloud when interpreting the instructions and experiencing any uncertainty.

When the actual user test began, participants performed the first task with the first method. After finishing the task, the participants answered questions regarding the first method. Two other tasks were completed, and questions were answered in the same manner.

After completing all three tasks, the participants had a short break, and were offered refreshments. The purpose of the break was to allow the participants to refresh their minds and get some distance from the previous task and method performed before answering the final part of the questionnaire. Finally, the participants answered questions comparing the methods as well as questions regarding smart glasses.

Results

First, all participants were very engaged with the user test. We did not measure user engagement per se, but we observed that all participants were focused, readily provided feedback, and showed intrinsic motivation during the tests [44]. Participants commented on other things than those primarily studied, and proposed improvements and modifications to components and products used in

TABLE III
PREFERENCE AND COMPREHENSION OF METHODS

Question	*N*	Result
Which version did you like the most?	20	Minimalist, *N* = 9 Visual manual, *N* = 7 Conventional, *N* = 4
Which version was the easiest to comprehend?	21	Minimalist, *N* = 10 Conventional, *N* = 6 Visual manual, *N* = 5

the test setup. They also gave feedback for the maintenance method used for the task and proposed alternative ways of performing the task. In addition, they discussed future maintenance guidance and proposed other areas where a similar system could bring benefits. All this confirmed high engagement and concentration from participants.

The preferred information design method among our test group was minimalist, followed by visual manual. The least liked method was conventional. Minimalist was rated the easiest to comprehend, conventional second, and visual manual last. The questions and results are presented in Table III.

As described earlier, the order of the tasks and methods was varied to avoid a bias that could be caused by participants favoring or disfavoring the method related to the task they performed first or last due to unfamiliarity with smart glasses or fatigue. This variability also addressed the bias caused by participants favoring or disfavoring a certain task.

There was a negative correlation between the method performed with the first task and the favorite method. Only two participants selected the method that they tried first as their favorite. Eight participants selected the last method as their favorite, and nine participants selected the middle one. One person omitted this question. There was also a negative correlation between the favorite method and the *Install motion sensor cable* task as only three participants preferred the one that they tested with the *Install motion sensor cable* task. Seven participants preferred the one they tested with the *Power-up Connection* task, and nine participants preferred the method they tested with the *Replace MediaPlayer* task.

Participants were requested to answer 12 questions for each method regarding the readability and understandability of the instructions on the screen, and the amount of text and number of graphics in the instructions. The results are presented in Figs. 11 and 12. In addition, participants were able to write free-form comments after each task regarding the task and the method.

Over 50% of participants agreed or totally agreed that there should be at least one graphic in each step, approximately 30% agreed or totally agreed that there should always be some text in each step, and approximately 30% agreed or totally agreed that there should always be both text and graphics in each step. Many participants commented that a combination of text and graphics complement each other especially with complex tasks: “There should always be an illustration for each step” (P1). However, with simple tasks it was not deemed necessary: “It is good that the very simple steps are not illustrated” (P2).

Participants were satisfied with the checklist type of reduced information; 48% disagreed or strongly disagreed with the question “I would like to have more explanatory text.” One third of participants were neutral, and only 9.5% of the participants agreed or strongly agreed. Participants also commented that the instructions described what was needed for task completion and that they did not need to assume or guess anything. Some participants named a specific task or detail for which they would have liked to have more explanation: “Where could I get more information about removing this part of the device?” (P3). These findings support our hypothesis of delivering reduced information and providing extra information only when the user needs and requests it.

With the visual manual instructions, people generally liked the concept but had problems recognizing when something needed to be done. For example, in deciding whether a graphic was a reference type of graphic only or whether they

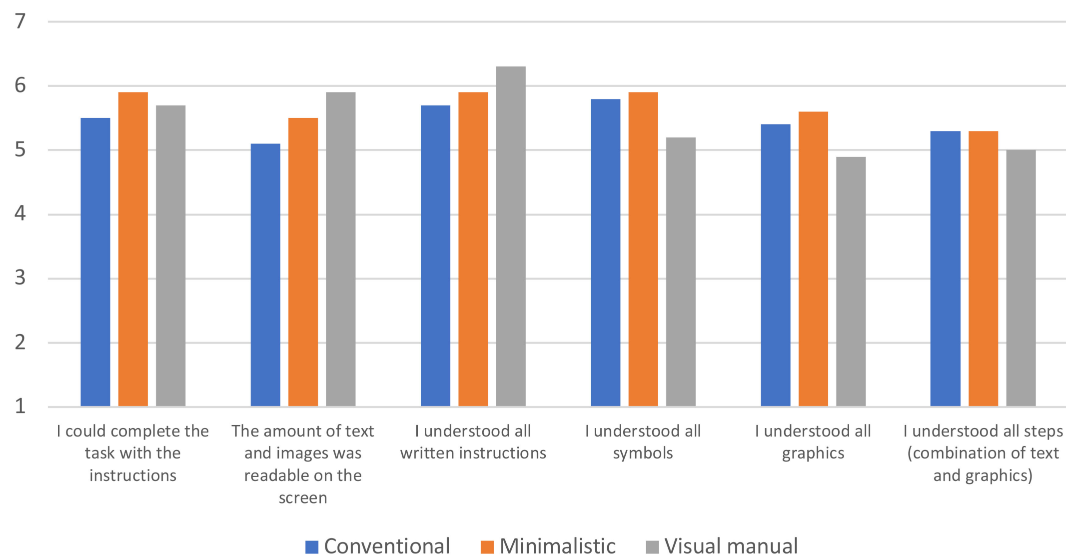

Fig. 11. Comments on methods, 1/2 (1 = totally disagree, 7 = totally agree), ($N = 21$). With these questions, the larger the value, the more positive the answer.

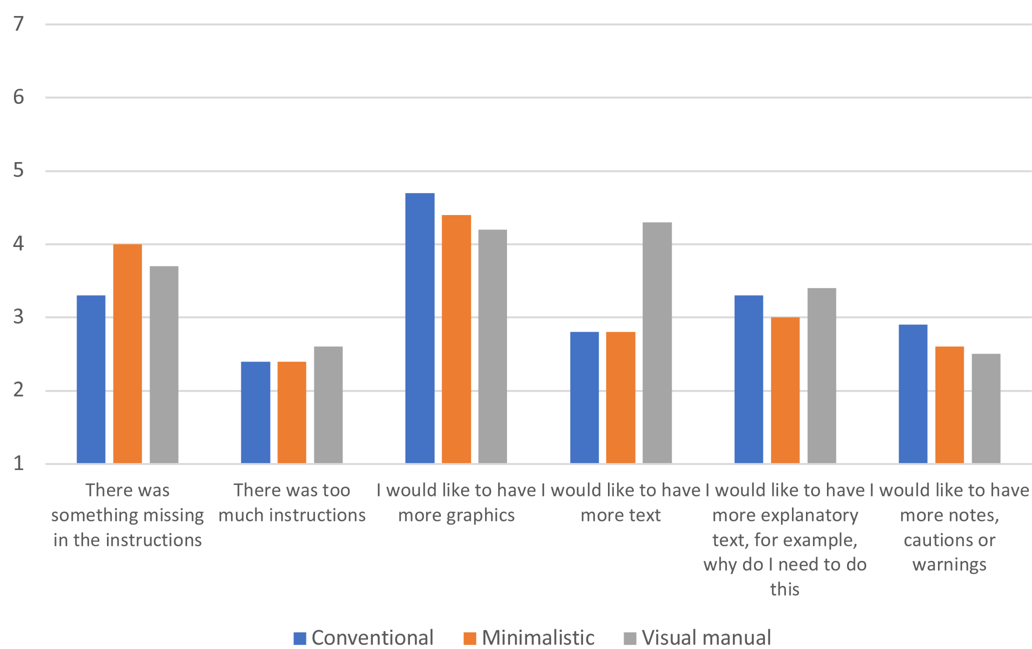

Fig. 12. Comments on methods, 2/2 (1 = totally disagree, 7 = totally agree), ($N = 21$). With these questions, the smaller the value, the more positive the answer.

needed to perform actions based on it, they might think aloud, “Do I need to do something now?” (P4) or “How do I know when I need to do something?” (P5). For one visual manual instruction (see Fig. 13), one screen consisted of a graphic that had several task symbols in it. The participants disliked the idea of several steps in one graphic and were also unsure whether the steps needed to be completed in a certain order: “There is so much information that I do not know where to start” (P1). This example revealed the need to clearly show one step at a time—that is, separated steps for *Drill hole* and *Route cable*.

Participants agreed that the amount of information was good for all the methods—that is, they were able to perform the tasks with the instructions provided. They felt that following the instructions one step at a time was more effective than scrolling up and down in a long list of steps that would not fit on the screen and would have required scrolling. Therefore, it can be noted that having the

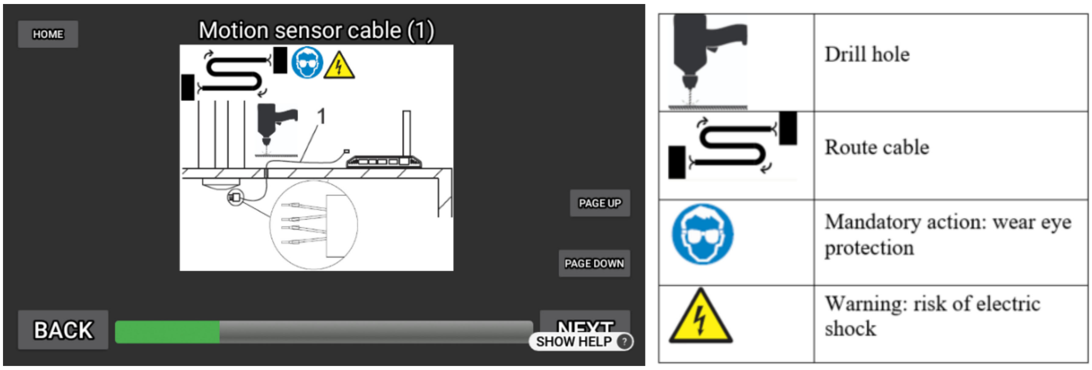

Fig. 13. Single graphic with several task symbols and legend from the visual manual (left). Symbols used in this instruction step (right).

TABLE IV
QUESTIONS REGARDING SMART CLASSES, ON A SCALE OF 1 = TOTALLY DISAGREE, 7 = TOTALLY AGREE (N = 21)

Question	Score	Rating Scale
The smart glass concept is something I could use in my daily work.	4.2	Neutral (3.4–4.5)
The use of smart glasses felt natural, did not hinder work.	4.2	Neutral
The use of smart glasses did not limit my awareness of the surroundings.	4.3	Neutral
The voice control operated well.	4.3	Neutral
The display was not in the way of my view.	4.8	Somewhat positive (4.6–5.7)
I was able to navigate and progress through the steps well.	5.3	Somewhat positive
The application UI was intuitive and easy to use.	5.6	Somewhat positive
The application worked well and ran smoothly.	4.7	Somewhat positive
I was able to read the text and graphics.	5.3	Somewhat positive
Instructions on smart glasses helps performing the task.	5.8	Very positive (5.8–7)

instructions proceed step-by-step on the screen was a well-received concept. However, the progress bar by itself was not enough to give a sense of location within the process for the participants. The relationship between steps and substeps was also not clear, and some participants even checked the next step to see what was coming before performing the step at hand: "I have a feeling that I need to check the next step here before doing anything" (P6).

Even though the list of the symbols used in the visual manual version was introduced to the participants before starting the task, and the participants were encouraged to check the meaning of symbols while doing the task, the visual manual approach scored the lowest for symbol understanding. Minimalism scored the highest in this category, followed by conventional. The conventional and minimalist versions used only symbols frequently included in maintenance instructions. Understanding all of the steps (a combination of text and graphics) followed this same logic: minimalist and conventional scored the highest, and the visual manual scored the lowest.

The visual manual scored high for the readability of text and graphics on the screen. The conventional manual scored the lowest, probably affected by the scrolling needed for some of the steps. Even though the conventional version had the most details and explanation, it scored the lowest for understanding all written instructions. The visual manual scored the highest for this category but admittedly had only a small amount of text. The minimalist scored above the conventional.

Smart glass use was generally received in a neutral or somewhat positive way (see Table IV). People were generally enthusiastic about the use of smart glasses, but as they are not yet a mature technology, that fact also showed in the evaluation of the concept. For example, some participants had problems with the voice commands and had to repeat the same command several times, causing frustration. The small screen of the HMT-1 was also difficult to use for some participants, and they had problems either seeing the instructions properly or focusing their eyes on the small screen. Therefore, further development is needed for devices and their user interfaces to apply smart glass use to industrial maintenance. However, participants strongly agreed that the instructions displayed on smart glasses helped in performing the tasks. Several participants commented that the step-by-step instructions were easy to follow and helped them perform the steps in the correct order: “With these instructions, anybody could complete the task” (P7) and “The smart glasses seem very useful; I like the concept very much” (P8).

Discussion

The aim of this research was to better understand how information content should be created and designed to support future use in addition to existing delivery channels. Our focus was to adapt checklist-type of technical information to small screens such as smart phones, smart glasses, smart watches, and other wearables. The user tests were conducted using smart glasses.

XR offers exciting possibilities for industrial maintenance. However, as the needs of the users should be the driving force when creating the content for these solutions, the content creation cannot be automated, and information design has a central role in the development of content for XR solutions [45]. Furthermore, users are not a homogeneous group. Because the background and expertise of maintenance technicians vary, their needs also vary. Xue et al. note that to improve the usability of AR-assisted maintenance systems, the information should be contextualized, for example, according to the user’s level of expertise and skills [18].

In our case study, we investigated the possibilities of delivering expert-level information through smart glasses. With the semantic tagging of DITA XML and competent information design, we could rely on certain elements containing the expert-level information and other elements containing the information needed for novices. Therefore, a straightforward filtering process of including and excluding information was utilized to contextualize the information according to a user’s level of expertise. This design also catered to the reuse of information because the same XML files could be used in other applications or outputs to resolve the full content, including the content excluded in our test application. As no conditions were required in the design of our materials, we could utilize the existing XML files without conditional processing.

Even though it has been argued that users of technical instructions do not have to memorize procedure steps, many company style guides set limits on step lengths or promote chunking into meaningful pieces to reduce cognitive load. Especially with hands-busy tasks, such as elevator maintenance, the delivery of maintenance instructions has been problematic. Users might need to memorize a sequence of steps if they are unable to utilize the mobile device to scroll down lengthy step lists or flip the pages of a paper manual while they are performing the task.

With XR solutions, however, the number of steps or chunks in a procedure becomes irrelevant as the users are able to follow the instructions simultaneously while performing the task. In our user tests, we utilized a design that proceeded step by step, one screen at a time. The participants were able to control the application with voice commands synchronously with the task at hand. The attitude of participants toward displaying information this way in smart glasses was very positive, and it was deemed to assist in task completion. However, the information must be carefully designed so that there is only one action on each screen; otherwise, users might skip an action or be unsure of the order of the steps.

We used different methods to compress the information. The conventional version based on the original instructions was used as the baseline version in this study. The preferred method among our test group was minimalist, followed by the visual manual approach. The baseline, conventional, was the least-liked method in the study. Even though conventional had the most description and details, it was rated lower than the other two for task completion. Therefore, it can be concluded that more details do not necessarily aid understanding or task completion if those details are not seen as relevant or necessary by the user. In contrast, with minimalism, the information is designed with a user-centered approach, and the focus is on providing the correct amount of detail that users need to perform the task.

Researchers have suggested that leaving out text altogether might be an option for XR solutions [34].

The visual manual approach is an enticing theory, especially in a global setting because of resulting low translation costs. In our case study, the basic idea of the visual manual was evaluated positively, but participants felt that leaving out text altogether made understanding difficult, especially with more complex tasks. It should be noted that in industrial maintenance, working environments pose hazardous conditions, and the unambiguousness of instructions is essential. Previous research has indicated that text leaves less room for interpretation than graphics, and that language can be used as a disambiguation tool for graphics [46]. Furthermore, as the understanding of symbols was not within the scope of our study, more research is needed to evaluate the comprehension of action symbols, specifically in a global multicultural setting.

Participants were asked to evaluate whether each step should always have at least one graphic, some text, or both. There was a considerable difference among the answers to these questions. On one hand, participants preferred visual objects, and stated that they helped in understanding the location of connectors, for example. On the other hand, unnecessary details hindered task completion, so specific guidelines about the use of graphics and text should not be enforced. Again, the user-centered approach promoted by minimalism is the best guideline for the use of text and graphics. A fusion between minimalism and the visual manual method would be worth investigating in the future, and enriching the XML content with animations, videos, and augmented reality elements would also be an interesting area for further research.

Even though the testing was done with smart glasses, the results are also applicable to other devices with small screens, such as, for example, smart watches. Correctly tagged and compressed information enables the generation of relevant content to various outputs.

Furthermore, many test participants proposed that a similar system could be used, for example, in installation, document review in product development, or training. These suggestions further confirm that there are many uses for this type of information delivery.

Conclusion

In our study, we evaluated different information design and information compression methods and the usability of maintenance guidance on small screens such as smart glasses.

We wanted to study whether users of technical instructions are ready to accept smart glasses and XR as a delivery channel, and our research confirms that instructions displayed on smart glasses help in performing tasks in industrial maintenance, and attitudes toward using smart glasses are positive.

In this case study, we also explored whether the same information content can be utilized to deliver relevant content to the users based on their skill levels. Filtering information with different DITA XML elements proved to be an efficient way to scale information for different user needs. In this study, we used this method to provide checklist type of information for expert users and leave out novice-level information. In the future, we will continue this study by implementing the possibility to get further instructions when needed to cater more to novice-level users.

Our third area of interest in this study was the design of information content so that it supports use in smart glasses and other small-screen devices in addition to existing delivery channels. Because smart glasses as a delivery channel for technical instructions is a new concept, literature is lacking in guidelines for the design and authoring of technical instructions targeted for small screens. Information created using the minimalism principles was the preferred information design method within our test group. It was also considered the most understandable. Therefore, the minimalism heuristics could be implemented more thoroughly in the future. The visual manual concept was also received well and, in general, the participants of our study wanted to have more visual content. However, the cultural understanding of symbols needs to be further studied before implementation.

Research papers very often focus on augmented reality instructions for maintenance guidance—that is, systems where the actions to be performed are animated on top of a machine. However, for a large number of maintenance tasks, the necessary information can be presented with graphics or text, and using 3-D augmentations would be overengineering. Thus, it is important to study ways to utilize more traditional instructions, based on graphics and text, in hands-busy situations. On the other hand, in some use cases, animations and augmentations would be beneficial and would bring extra value. Therefore, our proposal and area of further research is to embed augmented reality content in the XML files so that the viewer application can switch to the AR mode when the augmented content is available. In such a scenario, augmented content would be created only for complicated tasks, where the superimposed animations would help in task completion or accuracy, and the rest of the content would be derived from DITA XML files.

For industrial companies with tens of thousands of technical instruction sets, the capability to use the single source for multiple delivery formats without the need for constant tailoring would be a huge benefit. Our case study shows that well-designed technical information can be automatically used and delivered for several use cases and in several end devices, including displaying checklist-type maintenance information on smart glasses.

Appendix
Questionnaire

1. Gender
   a. Male
   b. Female
   c. Other/I don't want to tell
2. Age
   a. < 20
   b. 20-29
   c. 30-39
   d. 40-49
   e. 50-59
   f. > 59
3. Your working experience related to maintenance field work
   a. No experience
   b. Very limited experience of field environment
   c. Somewhat familiar with field environment
   d. Familiar with field environment
   e. I have worked at field myself / very experienced
4. Field of expertise (select all that apply)
   a. Maintenance
   b. Technical Documentation
   c. Installation
   d. IT
   e. XR
   f. Engineering
   g. Student
   h. Other
5. Task/theory [participants chose the combination they had been assigned and rated statements/answered questions 6-9 separately for each combination]
   a. Install motion sensor cable
   b. Power up KONE Connection
   c. Replace KONE MediaPlayer
   —
   a. Conventional
   b. Visual manual
   c. Minimalist
6. Content [Likert scale for each question 1-8, 1 = strongly disagree, 7 = strongly agree, 8 = no opinion/cannot evaluate]
   a. I could complete the task with the instructions.
   b. There was something missing in the instructions.
   c. The amount of text and images was readable on the screen.

   d. There was too much instructions.
   e. I understood all written instructions.
   f. I understood all symbols.
   g. I understood all graphics.
   h. I understood all steps (combination of text and graphics).
   i. I would like to have more graphics.
   j. I would like to have more text.
   k. I would like to have more explanatory text, for example, why do I need to do this.
   l. I would like to have more notes, cautions or warnings.
   m. All steps should have at least some text.
7. Was there something that could be left out? [free-form field]
8. Was there something that was missing? [free-form field]
9. Do you have any other comments of feedback? [free-form field]
10. Which version did you like the most?
   a. Conventional
   b. Visual manual
   c. Minimalist
11. Why? [free-form field]
12. Which version was the easiest to comprehend?
   a. Conventional
   b. Visual manual
   c. Minimalist
13. Why? [free-form field]
14. Images and text: [Likert scale for each question 1-8, 1 = strongly disagree, 7 = strongly agree, 8 = no opinion/cannot evaluate]
   a. There should be at least one image at each step
   b. There should always be some text at each step
   c. There should always be both text and images at each step
15. Smart glasses: [Likert scale for each question 1-8, 1 = strongly disagree, 7 = strongly agree, 8 = no opinion/cannot evaluate]
   a. The smart glass concept is something I could use in my daily work.
   b. The use of smart glasses felt natural, did not hinder work.
   c. The use of smart glasses did not limit my awareness of the surroundings.
   d. The display was on the way of my view.
   e. The voice control operated well.
   f. I was able to navigate and progress through the steps well.
   g. The application UI was intuitive and easy to use.
   h. The application worked well and ran smoothly.
   i. I was able to read the text and images.
   j. Instructions on smart glasses helps performing the task.

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