information

Article

User Interface Pattern for AR in Industrial Applications

Regina Koreng [1,*] and Heidi Krömker [2]

[1] Group Software for Testing Systems, Fraunhofer Institute for Ceramic Technologies and Systems IKTS, 01109 Dresden, Germany
[2] Media Production Group, Technische Universität Ilmenau, 98693 Ilmenau, Germany; Heidi.kroemker@tu-ilmenau.de
* Correspondence: regina.koreng@ikts.fraunhofer.de

Abstract: The background of the paper is that there are currently no specifications or guidelines for the design of a user interface for an augmented reality system in an industrial context. In this area, special requirements apply for the perception and recognition of content, which are given by the framework conditions of the industrial environment, the human–technology interaction, and the work task. This paper addresses the software-technical design of augmented reality surfaces in the industrial environment. The aim is to give first design examples for software tasks by means of sample solutions. For a user-oriented implementation, the methods of personas and an empirical investigation were used. Personas are a stereotypical representation of end users that reflect their characteristics and requirements. For the subsequent development of the pattern catalog, different prototypes with layout and interaction variants were tested in an empirical study with 50 participants. By observing the current realizations, these can be examined more closely in terms of their specific use in an industrial environment. The result is a pattern catalog with 26 solutions for layout and interaction variants. For the layout variants, no direct favorite of the testers could be ascertained; the existing solutions already offer a wide spectrum, which are chosen according to personal preferences. For interaction, on the other hand, it is important to enable fast input. During the study, gesture control revealed weaknesses in this regard. This can be supportive in the development of an industrial augmented reality system regarding a user-oriented representation of the interface.

Keywords: augmented reality; usability; industry; pattern; persona

check for updates

Citation: Koreng, R.; Krömker, H. User Interface Pattern for AR in Industrial Applications. *Information* **2021**, *12*, 251. https://doi.org/10.3390/info12060251

Academic Editors: Ramon Fabregat, Jorge Bacca-Acosta and Néstor Duque-Méndez

Received: 19 March 2021
Accepted: 9 June 2021
Published: 16 June 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Virtual augmented reality is currently experiencing a surge in development [1]. Smartphones and computers of all kinds have a camera as basic equipment and are constantly improving in terms of computing power. Recording the real environment and combining content at the same time is becoming easier.

Digitization in the industrial sector forms the basis for the integration of augmented reality (AR) [2]. It promotes the shift from analog to digital data. For example, data sent to servers by machines or products throughout the production process are processed digitally. The development effort for companies needs to be lowered so that AR can become more widespread and naturally integrated into industrial workflows.

The high heterogeneity of the user interface (UI) in commercially available head-mounted displays (HMD) makes it difficult for developers to find an ergonomically high-quality solution for the specific tasks in the production environment [3]. To maintain a high ergonomic level in the UI of an AR system in an industrial context, already proven UI elements and standards should be used. It is relevant to pay attention to consistency, controllability, self-descriptiveness, learning conciseness, and task appropriateness. In the production environment, which is characterized by many task-relevant stimuli, information in the AR glasses should be perceived and recognized very quickly and transferred into actions [4]. Currently, there are no generally applicable regulations that deal with the design

of a user-oriented UI. Several de facto standards have been formed by the market leaders of AR glasses. Problematically, no ergonomic quality of these solutions has been studied, but each model addresses some reported user difficulties. This results in a cognitive effort for the user, who is confronted with different layout solutions and interaction sequences of the manufacturers and must adapt to them. This reduces efficiency and effectiveness and increases the error rate. Regarding the industrial environment, no findings have yet been published and defined. Therefore, generic sample solutions for the user interface should be developed, which support the development and are valid for different industries. This paper deals exclusively with the software realization of the layout and selected basic interaction. A differentiated analysis of the hardware is not included.

2. State of the Art

A report from 2018 shows the development of AR/VR in comparison to 2016. It is clear that developments in gaming are declining and that the focus is more on research, marketing and retail [5]. Furthermore, reports clearly show that user experience is still the driving force behind the use of the technology and that attractive usage can only be achieved within the next three years [5]. However, the report also shows that there is great potential for specific tasks in the production environment.

In recent years, the interface of AR has been intensively studied. In 2016, Dey et al. analyzed 291 AR papers from 2005 to 2014 [2]:

- About 10% dealt with the industrial environment;
- About 35% dealt with HMDs, with a decreasing trend since 2010;
- About 24% obtained their results in field and pilot tests.

Thus, the research results from 2005 to 2015 provide little evidence to answer the above research question due to the heterogeneity of the technology used, application field, and evaluation method. In the years from 2015 onward, there have been only a few publications dealing with AR applications in an industrial context. Like Takatsu et al. [6], most papers dealt with the technical realizations, such as a digital service platform, exploring the integration of CAD data in an AR system [6]. Design guidelines and interface patterns were also developed by Billinghurst et al. [7] in their 2015 paper. They referred to the Games in Handhelds application domain. Nilsson [8] also investigated design patterns. He looked at display utilization, interaction mechanisms, and general design in handhelds. For the specific tasks in the industrial environment and the product life phases, Danielsson et al. [9] dealt with possible applications in the respective services. The various product life phases and the resulting generic tasks are discussed in Section 3.3.

Fundamental work on the classification of tasks and interactions in virtual contexts was done by Bowman, who distinguished between selection, positioning, and rotation tasks [10]. The following table shows Bowman's guidelines from 2005, which were adapted to current requirements by LaViola et al. in 2017 [11].

The guidelines for selection and manipulation require that existing techniques are used and that an exception is only made if there is identifiable added value. A trade-off should be made between technique, design, and the environment model. The guidelines for system control consider various forms of interaction techniques, for example, the forms of object visualization in 3D or 2D representations and control via gestures or focusing. The existing representation rules mainly refer to the design of the layout and the visibility of the feedback as well as to the interaction possibilities. In the layout design, the focus is on showing end user content that is perceived well and quickly. The guidelines on user comfort and safety deal with the temporal and spatial correspondence of the virtual and real worlds. Different colors or visible feedback can be used to guide the user. In this context, physical and virtual barriers can also be used to limit the free space. Table 1 shows the current recommendations for the realization of 3D user interfaces. Very partial guidance is given and not a holistic view of UI design. The guidelines of Bowman and LaViola are not fixed rules and are not focused on the specific context of the industrial environment. This current state, therefore, leads to the need for a separate study.

Table 1. Comparison of Bowman and LaViola 2005 and 2017 design guidelines.

2005: 3D User-Interface [10]	2017: 3D User-Interface [11]
Selection and Manipulation	
Use existing manipulation techniques unless a large amount of benefit might be derived from designing a new, application-specific technique.	
Use task analysis when choosing a 3D manipulation technique.	
Match the interaction technique to the device.	
Use techniques that can help to reduce clutching.	
Nonisomorphic ("magic") techniques are useful and intuitive.	
Use pointing techniques for selection and virtual hand techniques for manipulation.	Use pointing techniques for selection and grasping techniques for manipulation.
Use grasp-sensitive object selection.	Consider the use of grasp-sensitive object selection.
Reduce degrees of freedom when possible.	
Consider the trade-off between techniques design and environment design.	
There is no single best manipulation technique.	
System Control	
Avoid disturbing the flow of action of an interaction task.	
Prevent unnecessary changes of the focus of attention.	Prevent unnecessary focus switching and context switching.
	Design for discoverability.
Avoid mode errors.	
Use an appropriate spatial reference frame.	
Structure the functions in an application.	Structure the functions in an application and guide the user.
Consider using multimodal input.	
	3D is not always the best solution—consider hybrid interface.
User Comfort and Safety	
	Move wires and cables out of the way or use wireless solution when possible; reduce the weight of the equipment.
	Provide physical and virtual barriers to keep the user and the equipment safe.
	Limit interaction in free space; provide a device resting place.
	Design public systems to be sanitary.
	Design for relatively short sessions and encourage breaks.
	Design for comfortable poses.
Ensure temporal and spatial compliance between feedback dimensions.	
Use constraints.	
Consider using props and passive feedback, particularly in highly specialized tasks.	
Use Guiard's principles in designing a two-handed interface.	
Consider real-world tools and practices as a source of inspiration for 3D UI design.	
Consider designing 3D techniques using principles from 2D interaction.	
Use and invent magical techniques.	
Consider alternatives to photorealistic aesthetics.	

For the present paper, the following guidelines (see Table 2) can be derived from a combination of analytical and empirical analysis. The analytical studies summarize the heterogeneous design guidelines collected in widespread publications. The empirical studies focus on the reflection of these rules in the context of expert interviews. In this context, 10 experts from the industrial sector were interviewed, using a guideline.

Table 2. AR system specific operationalization of the dialog principles according to DIN EN ISO 9241-110 [12].

Category	Subcategory
	Task appropriateness
Focus on content [10,13,14], interview with experts	Preparation of content: • Without connection to upstream and downstream processes. • Task-centered and reduced. • Avoiding disruptive information.
AR input and output [10,12,14–23], interview with experts	Automatically start the AR program when the glasses are put on.
	Precisely match input to task: • Gesture control, such as main menu selection. • Tab sensing, such as "confirmations".
	Integration of signals: • Use acoustic signals only for a few selected situations. • Use visual signals preferentially. • Haptic signals are not applicable.
	Self-descriptiveness
Status information [10,13,14,17,18,23–30], interview with experts	Use of permanent displays at: • Orientation display, information mode, help system. • Main menu and relevant objects.
	Use of situational displays at: • Functionality of the system/operating instructions. • Provide information about required interactions in a timely manner. • Designing messages in a clearly recognizable way.
	Use of feedback for: • Selection of objects. • Scaling of objects.
	Use of general design: • Not overwhelming. • Tailoring information to the task at hand. • Support intuitive and emotional operation.
Basic interaction [10,13,14,17,19,20,24,28,30–33], interview with experts	Display of all possible interactions.
	Designing sequences of interactions in a process- and interface-oriented manner.
	Design and coding of manipulation techniques, such as the reset function.
	Use hidden information ("ghost views") to reduce information.
	Conformity to expectations
Description of the product as a model [13,33], interview with experts	Represent product with reduced background or context geometries; use realistic and familiar object geometries.
	Focus on the product.

Table 2. *Cont.*

Category	Subcategory
AR system [10,14,16,34], interview with experts	Field of view of AR glasses should largely correspond to natural human field of view (horizontal~180° vertical~120°).
	Interaction with the AR system should be consistent, self-explanatory, and oriented to what has already been learned.
	Learning conciseness
Context-specific information [13,19,25,29], interview with experts	Hints facilitate operation/interaction.
	More detailed information should be displayed if required.
	Specific product criteria are displayed as action hints for employees.
	Controllability
Software supports the various tasks [13], interview with experts	AR system contains hints for physical tools.
	AR system uses the pointing capabilities of humans with their hands for interaction.
User is guided [13,25,33], interview with experts	Situational information display depending on work activity.
Depth cues [13,14,19,20,24,28,30,33,35], interview with experts	Giving depth cues in a task-oriented manner.
	Supporting the perception of depth cues with tools.
Controls [10,14,16,17], interview with experts	Designing gesture and tab sensors to be clearly controllable.
	Tolerance for errors
Input/Output [10,13,14,19,26,27], interview with experts	Software recognizes incomplete terms in voice commands.
	In the case of incorrect input and output, reliability is supported by auto-completion or queries.
	Individualizable
Modes of presentation and interaction [13,14,19,25], interview with experts	Individualizable display of information about the product or interaction.
	Display variants: • Alternative 3D models for understanding. • Different widgets for object control, such as for scaling.
	Offer different modes of interaction, such as speech and gesture.

For the specific requirements, the dialog principles from DIN ISO 9241-110 [12] were categorized for task appropriateness, self-descriptiveness, conformity to expectations, learning conciseness, controllability, tolerance for errors, and being individualizable. For example, it is required that information in the AR system should be understandable independently of upstream or downstream processes; otherwise, the information volume would be too high for the completion of the individual task. Furthermore, the status information should clearly distinguish between permanent and situational displays. The main menu and orientation displays should always be available to the user, while messages should be faded in and clearly recognizable. For the industrial context, the field of view of the AR system should also be used to its full extent to correspond to the human field of view. If, in addition, information about physical tools is transmitted via the AR system, reality can be completely overlaid with virtual content.

3. Materials and Methods

3.1. Persona

For the paper, a specific examination of the end user is relevant to capture special needs and characteristics. Personas are suitable for this purpose. These give a fictitious but specific representation of the end user. By using stereotypes, the goals and behaviors of real users can be derived. Personas are derived from information about future users and reflect characteristics relevant to the AR system [36–38].

In the literature, despite the emphasis on different advantages (see Table 3), there is a consensus that personas generate a better understanding of the target groups in design teams [38–40]. Using personas can be considered a powerful and versatile design tool. In the paper, the persona method is used across all studies to continuously focus on the end users and the work task. In this way, identification with the users takes place, which is still important in the development of the layout variants.

Table 3. Advantages of using personas.

Source	Advantages
Cooper (1999) [38]	• Increase focus on the users and their goals. • Facilitate effective communication about users. • Reduce necessary changes at the end of the development process.
Cooper and Reimann (2002) [39]	• Build consensus and commitment to design. • Help to measure a design's effectiveness. • Define the product's feature set. • Facilitate effective communication within the project team. • Help other related efforts such as marketing plans.
Grudin and Pruitt (2002) [38]	• Facilitate a focus on users and work contexts. • Allow for extrapolation from partial knowledge of users to diverse contexts. • Make assumptions about users explicit. • Facilitate effective communication about the users. • Increase focus on a specific audience.
Long (2009) [38]	• Strengthen focus on the users during the development process. • Lead to more user-friendly designs. • Make the user needs more explicit. • Guide decision making.
Ma and LeRouge (2007) [38]	• Facilitate effective communication about the users. • Enhance identification with the target users. • Increase focus on user needs.
Mayas, Hörold and Krömker (2016) [39]	• Holistic integration of user requirements. • Facilitates prioritization of requirements. • Method for adequate documentation of user requirements. • Unrestricted identification of users and scenarios. • Facilitate validation of requirements.
Pruitt and Adlin (2006) [38]	• Make assumptions about users explicit. • Narrow the users being designed for. • Lead to better design decisions. • Increase engagement among the design team. • Build empathy for the users.

In the paper, five aids from Cooper et al. [36] are used. The focus is especially on the users' goals and the identification of behavior patterns [36]:

- The basis for the design effort is formed by personal goals and tasks.
- Personas provide a basis for design decisions and help to ensure that the user is in focus at every step of development.
- Personas make it possible to form a language and thus a common understanding.
- Design decisions can be measured by a persona as well as by real subjects.

- Multiple business units within a company can make use of personas.

For making personas, both Cooper et al. and Pruitt and Adlin [36,37] identified characteristics and behavioral variables that should be captured in a persona. The following should also be included in an adapted manner:

- Description: Name and picture.
- Characteristics: Age, education level, lifestyle, role/professional position.
- Knowledge: Basic attitude, technology knowledge, and technology attitude.
- Concerns and goals: Expectations, qualifications, and goals.
- Activities: Tasks and activities.

These personas should be identified for all areas of product development. In a study on persona development, 40 representative people selected by the companies were interviewed. The subjects worked in four different companies (automotive consumer goods, industrial goods special machinery, industrial goods mechanical engineering, and research product development) and eight professional levels (development, management, engineer, marketing/sales, planning, quality control, engineering, and training) [41]. Using the interview method with subject-matter experts and developers from the industrial environment, the behavioral variables were analyzed. With the help of a guide, questions related to career path, current job, and work environment were asked. Tables 4 and 5 show, following Pruitt and Adlin, the summary of the characteristics in relation to the traits and behavior variables.

Table 4. Analysis of persona development data.—Gender and Age.

Gender	N = 40	Age	N = 40
Male	85%	<25 years	12%
Female	15%	25–34 years	35%
Divers	0%	34–44 years	20%
		45–54 years	25%
		>54 years	8%

Table 5. Analysis of persona development data.—Occupational specialties.

Occupational specialties	N = 40
Development	7%
Management	15%
Engineer	23%
Marketing/Sales	7%
Planning	10%
Quality Control	7%
Engineering	28%
Training	3%

Based on the available results of the target group investigation, four personas were determined, which are representative. In this way, the persona's planner, technician, quality inspector and trainer were defined. It was observed that the characteristics of the analyzed end users are reflected in the personas. The structure of the personas follows the pattern described above. Each persona was given a name and age, which were chosen fictitiously, and a professional position. Subsequently, the areas of responsibility, expectations and education were determined. Finally, the persona's personality and its use of the AR system were described. Figure 1 shows the four personas (planner, trainer, quality inspector, and technician) that were extracted from the research.

Each persona is representative of a typical user in the life phases of product planning, development/design, manufacturing/assembly, and use. These personas are relevant to the following phases in the research design. They were obtained from the interviews conducted with the representative persons. The description of the range of tasks was given by the respective professional position. Different areas of the life phases were chosen for a wide range of activities. This field then also influences how the persona uses the AR end device. Personal differences occur in expectations and personalities. The interviews were chosen as the basis.

The visualization alternatives were matched to the tasks of the personas. Specifically, this means that icons and buttons, for example, should be generally understandable. Independent of the personas' personal knowledge, an operation should be easy to learn and understand. This also results in the acceptance of the AR end device in everyday work. In this paper, these personas are a powerful methodological tool for the requirements of analysis, design definition, and pattern evaluation.

Name	Roman Berger
Professional position	Planer
Age	42
Field of activity	Design and development of products. There is a close cooperation with the respective project management and the customer. Thereby the requirements and wishes of the customer flow into the (new) development.
Expectations	• proper testing and measuring tools. • documentation of previous projects/products
Education	• dual vocational training
Personality	• product-oriented • with an affinity for technology • able to work in a team
Use of the AR-System	• presentation of the current planning status • individual adaptation of the product

Name	Sandra Rothenburg
Professional position	Trainerin
Age	36
Field of activity	Training scenarios for workshops and trainings. By working together with customers, specific training scenarios can be created and carried out on the products. Often a detailed description and instruction of the products is provided.
Expectations	• knowledge of equipment and products
Education	• dual vocational training
Personality	• product-oriented • able to work in a team • creative
Use of the AR-System	• operating instructions of the products • practice scenarios during the training

Figure 1. *Cont.*

Name	Filip Ziegler
Professional position	Quality inspector
Age	51
Field of activity	Testing of products according to specified test plans. By using mechanical, optical and electronic devices, the inspection of the finished products is carried out. The sequence and frequency of testing cycles are specified by the customer.
Expectations	• proper testing and measuring tools • knowledge of equipment and products
Education	• dual vocational training
Personality	• product-oriented • critical • technophile
Use of the AR-System	• functional testing of products • goods inspection of the end products

Name	Nadine Bergmann
Professional position	Technician
Age	29
Field of activity	Development and construction of machines and plants. Tasks vary from assembly and maintenance of the machine needed to manufacture the products.
Expectations	• proper testing and measuring tools • knowledge of equipment and products
Education	• dual vocational training
Personality	• solution-oriented • product-oriented • structured
Use of the AR-System	• compilation of suitable machine elements and products • knowledge of the current stock

Figure 1. Persona (from top left to bottom right: planner, trainer, quality inspector, and technician).

3.2. The Background of Pattern

In 1977, Alexander et al. [42] introduced the term pattern in their publication "A Pattern Language". For problems that occur again and again, pattern solutions, so-called patterns, can support the solution. Patterns not only describe the problem, but they also describe the core of the solutions. These can then be reproduced infinitely [42]. These views were also supported by Mahemoff and Johnston in 1998 [43]. They saw patterns as a compromise for examining design alternatives for their suitability. Competing options can be considered to focus on the problem [43]. Similarly, van Duyen et al. [44] commented on this issue. Every solution also has opposing forces that need to be addressed. In this context, these forces can be seen as different needs and constraints. The patterns should show the advantages and disadvantages of each alternative solution and serve as decision support [44].

Patterns do not represent fixed regulations or specifications that restrict a development. They are intended to serve as tested suggestions for finding solutions to recurring problems in the development of user interfaces for AR systems in an industrial context and to inspire them. Each pattern can be flexibly transferred to other application areas according to the described solution [45]. For easy and clear manageability, the patterns should have the same shape. Each pattern solution should contain a picture as well as a description. In this regard, both the problem and the solution should be described in more detail so that it is apparent how the pattern can be helpful. The solution may include instructions on how to apply the pattern. Proof of validity is often provided by solutions proving themselves over time in everyday use. Since there is a high need for new technologies to have design quality early on, usability testing is used to empirically prove their worth [42].

Kunert [45] showed in his dissertation that most developers of a user interface need certain information in a pattern. Furthermore, Kunert [45] dealt with the structure of patterns. In a study with UI designers, not only the relevant requirements were discussed, but also the structure of the patterns. In terms of content, the UI designers specified that the identification and integration of patterns should be described as part of the design process. Furthermore, a discussion and justification of the design alternatives should be made. For a uniform and clear presentation, the patterns should be written in table form. According to Kunert, this allows UI designers to get a direct overview of which layout problems the patterns describe and which alternative solutions are proposed. For the catalog with patterns of the AR system, the elicited template from Kunert's dissertation is used, which deals with concrete problems [45].

Table 6 shows the description categories, such as problem, solution, proof, and potential, which proved to be helpful for the developers.

Table 6. Structure of the pattern.

Category	Category of the pattern
Name	Name of the pattern
Problem	Description of the representation problem
Solution	Description of the alternative solution
Evidence	Evidence by a usability test
Potential	Potential of the pattern
Related patterns	Similar patterns
Representation	Graphical representation of the pattern

3.3. The Creations of Pattern

The creation of the patterns is determined based on two questions:

- Which core work tasks are performed in the production environment with AR glasses?
- Which core structures do the UIs of existing layout solutions on the market have?

Patterns are to be extracted for the production environment based on the previously mentioned personas. The product life phases in which AR can be used range from product planning, design and manufacturing to assembly and use [4,46]. Figure 2 shows the systematic as well as the results of the task and interaction analysis conducted with all target groups following the personas.

First, the generic tasks that are present in the use of AR in the product life phases were extracted:

- Selecting from the menu: The complex industrial content is prepared in a work-situated manner via entry points.
- Navigating documents: Manufacturing documents or assembly instructions are generally long documents with an average number of pages of about 20–30 DIN A4 pages.

- Deepening object information: Additional information is offered for the work objects in the real world.
- Selecting from the toolbar: Basic functions are arranged here, such as minimize, maximize, back, close, help, save, which are frequently used.

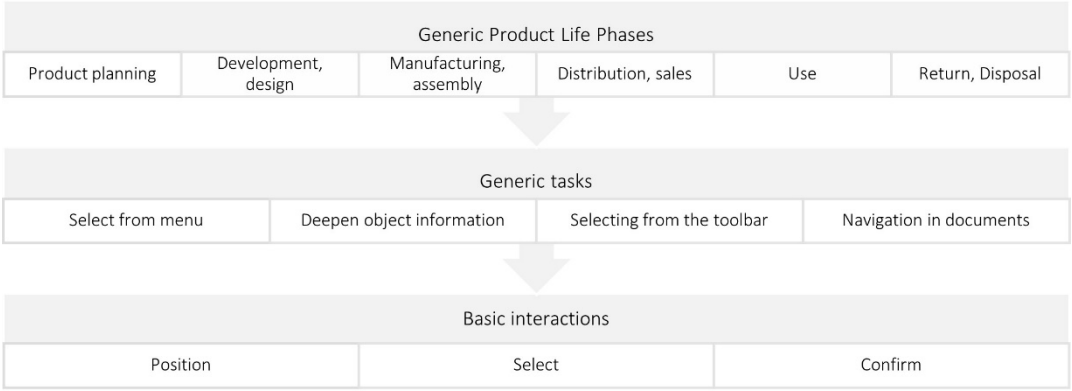


Figure 2. Representations of prototypical tasks in an AR system [3,47].

From these generic tasks, following Bowman et al. [10], the basic interactions were extracted that occur in every dialog:

- Position: The cursor is moved to buttons, such as toolbars.
- Select: The desired button is selected, and the system indicates the selection with an appropriate marker.
- Confirm: The input confirms the selection.

The selection of these actions seems limited, but it is exactly the lowest common denominator of the interactions that the named personas perform. They thus provide a stable, generic starting point for the differentiation of further interactions.

The study on the evaluation of layout variants in AR systems is based on an empirical investigation with best practice variants that have already been successfully established on the market. The goal is to extract proven solutions and describe them in patterns. The analysis of existing systems serves as a basis for further investigation and implementation. Four data glasses producers were considered for the study [41]. Microsoft HoloLens 1 and Daqri are representatives of glasses already found in manufacturing and industrial applications. Meta 2 and Magic Leap One are used in the consumer sector [41]. The heterogeneity of the layout makes it difficult to decide on an implementation variant for industrial use. This leads to testing the current possibilities among each other. The following table shows the different layout and interaction structures that were formed from the analysis of the manufacturers, which will be examined in more detail below.

The layout variants form possible variations for design options. As an example, Table 7 shows an example of a design of the main menu. Here, three variants (tile, list, circle) are examined with respect to gesture input and interaction by focus. The method of usability testing with a high number of test subjects is chosen. The test subjects correspond to the user profiles—the persona. The test task includes the generic basic interactions. For evaluation, the usability measures and the measure of usefulness are examined.

Table 7. Generic tasks that are examined in the study.

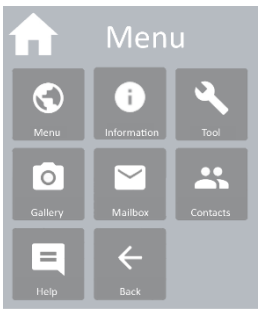
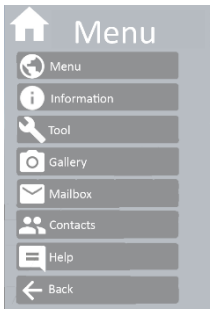
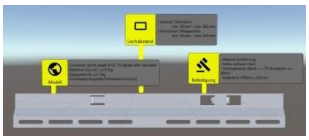
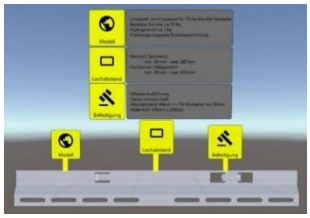
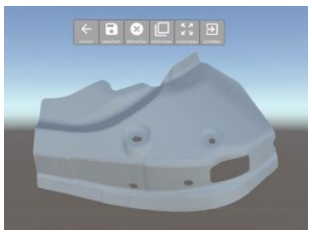
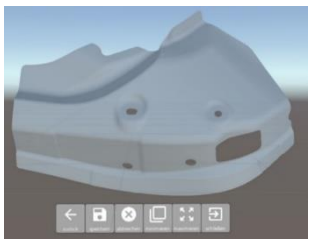
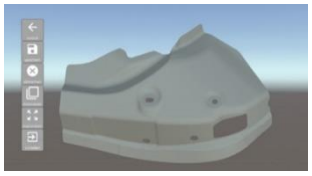
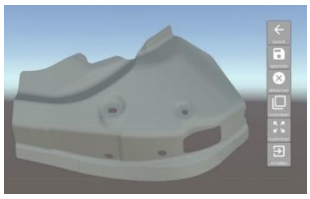
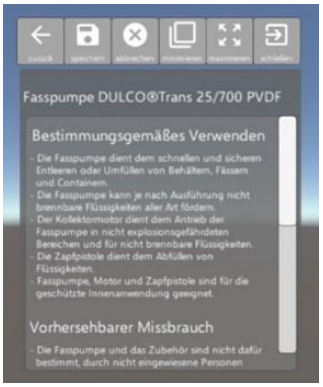
Generic Task	Alternative Representations	
Select from menu	Shape of the main menu: Tile	
	Input: Gestures	Input: Focus
	Shape of the main menu: List	
	Input: Gestures	Input: Focus
	Shape of the main menu: Circle	
	Input: Gestures	Input: Focus
		
Deepen object information	Position of information: Near object	
	Input: Gestures	Input: Focus
	Position of information: Far from object	
	Input: Gestures	Input: Focus
		
Selecting from the toolbar	Position of the toolbar: Top	
	Input: Gestures	Input: Focus
	Position of the toolbar: Bottom	
	Input: Gestures	Input: Focus
	Position of the toolbar: Right	
	Input: Gestures	Input: Focus
	Position of the toolbar: Left	
	Input: Gestures	Input: Focus
		

Table 7. *Cont.*

Generic Task	Alternative Representations
	
Navigation in documents: Split screen/full screen	Type of navigation: Browse
	Input: Gestures and focus
	Type of navigation: Scroll
	Input: Gestures and focus
	

DIN EN ISO 9241-11 defines usability as "the extent to which a product can be used by specific users in a specific context of used to achieve specific goals effectively, efficiently, and satisfactorily." [48] The AR system is thus used by users in the context of the work task in an industrial environment. To determine whether the goal of user-friendliness is achieved, the usability measures are taken as an aid. In this context, the three terms are defined by ISO standard 9241-11 [48]:

- Effectiveness.
- Efficiency.
- Satisfaction.

By separating the product life phases into generic tasks and basic interactions, the individual steps to be performed with the AR system become clear. Figure 2 (see page 11) illustrates the four tasks that are generically applicable to all six product life phases. For example, "selecting from menu" is extracted. This task is relevant for the user to access the available options via the main menu. Furthermore, it must be possible to call up additional information of the objects as well as the function bar. Finally, "navigating in documents" is relevant so that the user can carry all documents with him/her and access them at any time. All generic tasks contain the basic interactions of positioning and selecting with the cursor and the subsequent confirmation of the input.

The derivation of these basic interactions from the generic tasks were used as test tasks for the evaluation of the layout variants. For the design of the layout variants, existing data glasses layouts were considered to consider all design components for high usability and usefulness.

The study on the evaluation of layout variants in AR systems was based on an empirical investigation. The goal was to extract proven solutions and describe them in patterns. The layout variants formed possible variants for design options. The method of usability testing with a high number of test persons was chosen. The test persons corresponded to the personas (Section 3.1) and were all from the industrial environment.

4. Evaluation of the Pattern Catalog

As shown in Section 3.3, the layout variants were evaluated in a direct comparison of the usefulness measure and the usability measure for the different alternatives. Figure 2 shows the five different tasks that were performed by the test persons. For the evaluation, 50 probands from the industrial environment were selected according to the personas. Tables 8 and 9 show the evaluation with respect to the demographic data [41]. For each of the generic tasks, several layout variants are provided, which must be evaluated in direct relation to each other. It is important whether the layout of the test task supports the respondent, how effective and efficient the presentation is and how satisfied the respondent is with it. For the interpretation of the results, and thus as a conclusion for the hypotheses, it is relevant that at least one dimension shows a significant difference. The evaluation illustrates which alternative was rated better by the 50 test persons.

Table 8. Evaluation of demographic data.—Gender and Age.

Gender	N = 50	Age	N = 50
Male	78%	<25 years	10%
Female	22%	25–34 years	36%
Divers	0%	34–44 years	28%
		45–54 years	20%
		>54 years	6%

Table 9. Evaluation of demographic data.—Occupational specialties.

Occupational specialties	N = 50
Development	6%
Management	14%
Engineer	24%
Marketing/Sales	8%
Planning	8%
Quality Control	8%
Engineering	30%
Training	2%

The complex industrial content is presented in a work-oriented manner via menu entry points. On average, there are about five menu options to choose from. The menu is shown to the user in the AR system at the beginning and is then hidden so that the display is available to show other content. In the course of the work process, it must then be consciously called up again. The menu options of the main menu are thus only available situationally. The different alternatives for selecting from the main menu showed that the circle display was favored over both the tile and the list. These ratings indicate that familiar representations were important to the subjects for the layout.

5. Final Catalog with Pattern

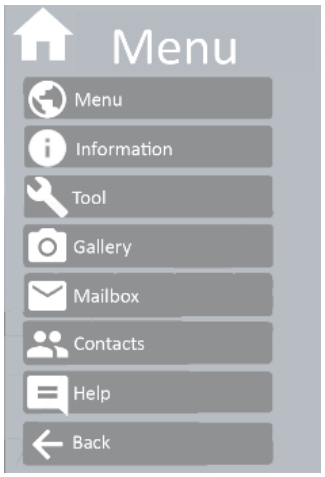
In the UI study, the individual layout variants were examined and assessed regarding the criteria of effectiveness, efficiency, and satisfaction as well as usability for the respective design problem. The results were summarized as a starting point for the development of the catalog with patterns for an AR interface in industry. For the study, 50 subjects from the industrial environment from different industries were interviewed [41]. The findings show that good solutions already exist for the design of certain functions and that different solutions for a problem achieve comparably good results in the evaluation. The degree of fulfillment of each criterion can range from a maximum value of 5 (exceptionally good) to a minimum value of 1 (extremely poor). The Table 10 shows the mean values (M) for each alternative. If one of the four criteria contains a value below three, the layout or interaction variant is considered critical and it is to be used with reservation. From two values below three, the variant is not included in the catalog with pattern, because they cannot be considered to be a proven sample solution.

Table 10. Extract from the evaluation of layout variants.

Generic Task	Usefulness (M)	Effectiveness (M)	Efficiency (M)	Satisfaction (M)
Select from menu				
Tile	3.90	4.06	3.14	3.86
Deepen object information				
Information about the object	2.96	3.22	2.44	3.04
Selecting from the toolbar				
Function bar on the right	3.48	3.90	2.66	3.50
Navigation in documents				
Scroll reading style	2.56	2.78	2.44	2.44
Select from menu: Tile				
Interaction through gestures	3.91	4.09	2.95	3.86
Deepen object information: Information about the object				
Interaction through focus	3.48	3.76	2.86	3.57
Selecting from the toolbar: Function bar on the right				
Interaction through gestures	3.75	4.04	3.02	3.71

This evaluation also suggests that the user interface in an industrial context should allow for multiple alternatives in both layout design and interaction. The composition of the patterns is based on these results. As described in Table 6 (see page 10), the patterns are all built according to the same pattern [41]. Table 11 shows an example of a complete pattern for the "Select from menu" layout variant list.

Table 11. Example of a pattern: Select from menu-list.

Category	**Generic Task: Select from Main Menu**
Name	Layout variant: Main menu as list
Problem	The user has several applications and contents at his disposal. For an overview of the different contents the user needs a main menu.
Solution	The main menu is displayed when the AR device is started. The information is available to the user situationally and must be called up specifically. A list-like display has a high recognition value, as it is already frequently used in industrial applications. Users are thus familiar with the design. The menu in the form of a list allows the user to view the complete contents of the main menu immediately. The complete contents of the main menu immediately. It can be expanded in list elements as well as in depth, but care should be taken to keep the main menu as such and to form suitable subgroups.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.40 out of 5.00 points Rating effectiveness M: 3.88 out of 5.00 points Rating efficiency M: 3.14 out of 5.00 points Evaluation satisfaction M: 3.34 out of 5.00 points
Potential	Extension of the list in length Sorting of contents according to relevance Reduction of content to icons
Related patterns	Main menu as tile Main menu as circle Main menu as tile-interaction by gestures/focusing Main menu as list-interaction by gestures/focusing Main menu as circle-interaction by gestures/focusing
Representation	

Tables 12 and 13 show short excerpts from the other pattern that were created in connection with the main menu. Part 1 shows the three patterns for the design of the layout and part 2 shows examples for the design of the interaction.

Table 12. Examples from the catalog with pattern. Part 1: Variants of the layout.

Category	**Generic Task: Select from Main Menu**	**Category**	**Generic Task: Select from Main Menu**
Name	Layout variant: Main menu as tile	Name	Layout variant: Main menu as circle
Problem	The user has several applications and contents at his disposal. For an overview of the different contents the user needs a main menu.	Problem	The user has several applications and contents at his disposal. For an overview of the different contents the user needs a main menu.
Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. A tile-shaped display has a recognition value since it is applied to current Windows PCs. Users are thus familiar with the design. The main menu in the form of a tile enables the user to view the complete contents of the complete contents of the main menu briefly. The tiles are arranged as a matrix and can go into any depth. It should be noted that the matrix does not become too detailed and thus lose the character of the main menu.	Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. A circular display has a recognition value from the gaming field, and it has similarities with the tile display. The main menu in the form of a circle allows the user to see the complete contents of the main menu briefly. The circle corresponds to round arranged elements and has the main category in the center. The circular representation allows a limited number of extensions per level but can be extended in depth.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.90 out of 5.00 points Rating effectiveness M: 4.06 out of 5.00 points Rating efficiency M: 3.14 out of 5.00 points Evaluation satisfaction M: 3.86 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.52 out of 5.00 points Rating effectiveness M: 3.74 out of 5.00 points Rating efficiency M: 3.20 out of 5.00 points Evaluation satisfaction M: 3.60 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Deepen object information	Category	Generic task: Selecting from the toolbar
Name	Layout variant: Position of information: near object	Name	Layout variant: Function bar top
Problem	The user should be shown additional information about a specific object or product. The user should be able to quickly grasp and retrieve this information.	Problem	While the user is in an application, a toolbar is needed so that the current position can be left.
Solution	For 3D models and objects, additional information can be provided to the user. This can be called up situationally using icons. To place the information at the appropriate place and in the field of vision of the user, it is recommended to display the content directly on the object. In this way, an icon symbolizes to the user that information is available. By pressing the icon, this additional information is retrieved from the user. If this information is no longer needed, it can be closed again. Due to the different placement of the contents, there is no overlapping of information. Placing the information directly at the object offers the advantage that an exact assignment can be made.	Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar at the top is perceived directly by the user. The toolbar can be placed over textual content as well as over graphical elements. It is the permanent constant in the application and ensures that the user can always return to the main menu or save content. Most applications on the PC have their function bar in the upper area, which leads to a high recognition value among users.

Table 12. *Cont.*

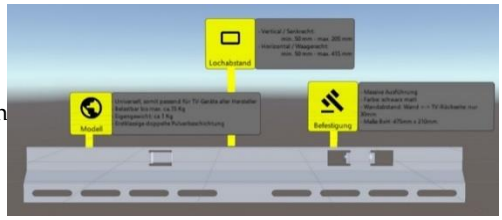
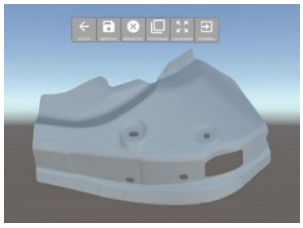
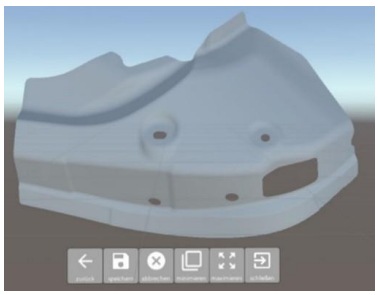
Category	Generic Task: Select from Main Menu	Category	Generic Task: Select from Main Menu
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 4.56 out of 5.00 points Rating effectiveness M: 4.56 out of 5.00 points Rating efficiency M: 3.68 out of 5.00 points Evaluation satisfaction M: 4.56 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.86 out of 5.00 points Rating effectiveness M: 4.10 out of 5.00 points Rating efficiency M: 3.10 out of 5.00 points Evaluation satisfaction M: 3.70 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Selecting from the toolbar	Category	Generic task: Navigation in documents—split screen
Name	Layout variant: Function bar bottom	Name	Layout variant: Scrolling reading style
Problem	While the user is in an application, a toolbar is needed so that the current position can be left.	Problem	The user is provided with short texts in a split screen while working with the AR system. To avoid texts that are too long, sensible divisions should be made.
Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar at the bottom is perceived directly by the user. The toolbar can be placed under textual content as well as under graphical elements. It is the permanent constant in the application and ensures that the user can always return to the main menu or save content. The current PCs have a function bar at the bottom of the screen in their basic settings, so recognition can be generated among users.	Solution	Textual information can be provided to the user in the AR system. The text is called up specifically and must be quickly grasped by the user. Scrolling is suitable for navigating through single-column texts on a split screen in an AR system. The content sections of the individual pages enable the user to quickly grasp information. Furthermore, scrolling allows the user to review sections that have already been read. Scrolling is done by arrows above the text and indicates the number of pages at the bottom of the screen. The advantage of scrolling is that it can be designed like reading in a book; by labeling the page number, the user gets an overview of the scope.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.44 out of 5.00 points Rating effectiveness M: 4.98 out of 5.00 points Rating efficiency M: 3.16 out of 5.00 points Evaluation satisfaction M: 3.30 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 4.34 out of 5.00 points Rating effectiveness M: 4.28 out of 5.00 points Rating efficiency M: 3.68 out of 5.00 points Evaluation satisfaction M: 4.16 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	

Table 13. Examples from the catalog with pattern. Part 2: Variants of interaction.

Category	**Generic Task: Select from Main Menu**	**Category**	**Generic Task: Select from Main Menu**
Name	Layout variant: Main menu as tile Interaction variant: Interaction through gestures	Name	Layout variant: Main menu as tile Interaction variant: Interaction through focusing
Problem	A range of applications and content is available to the user. For an overview of the different contents, the user needs a main menu. Therefore, the interaction with the main menu is relevant for the user.	Problem	A range of applications and content is available to the user. For an overview of the different contents, the user needs a main menu. Therefore, the interaction with the main menu is relevant for the user.
Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. The main menu in the form of a tile allows the user to view the complete contents of the main menu briefly. With this form of presentation, interaction via gesture control is suitable. The action is deliberately and specifically triggered by the user through a hand movement. **Attention:** One hand must always trigger the action, which does not allow complete hands-free work.	Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. The main menu in the form of a tile allows the user to view the complete contents of the main menu briefly. In this form of presentation, the interaction is suitable by focusing with the eye. The action is only triggered after a set period and enables complete, hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.91 out of 5.00 points Rating effectiveness M: 4.09 out of 5.00 points **Rating efficiency M: 2.95 out of 5.00 points** Evaluation satisfaction M: 3.86 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.84 out of 5.00 points Rating effectiveness M: 4.15 out of 5.00 points Rating efficiency M: 3,21 out of 5.00 points Evaluation satisfaction M: 3.90 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Select from main menu	Category	Generic task: Select from main menu
Name	Layout variant: Main menu as list Interaction variant: Interaction through gestures	Name	Layout variant: Main menu as list Interaction variant: Interaction through focusing
Problem	A range of applications and content is available to the user. For an overview of the different contents, the user needs a main menu. Therefore, the interaction with the main menu is relevant for the user.	Problem	A range of applications and content is available to the user. For an overview of the different contents, the user needs a main menu. Therefore, the interaction with the main menu is relevant for the user.
Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. The main menu in the form of a list allows the user to view the complete contents of the main menu immediately. With this form of presentation, interaction via gesture control is suitable. The action is deliberately and specifically triggered by the user through a hand movement. **Attention:** One hand must always trigger the action, which does not allow complete hands-free work.	Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. The main menu in the form of a list allows the user to view the complete contents of the main menu immediately. With this form of presentation, the interaction is suitable by focusing with the eye. In this form of presentation, the interaction is suitable by focusing with the eye. The action is only triggered after a set period and enables complete, hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.

Table 13. *Cont.*

Category	Generic Task: Select from Main Menu	Category	Generic Task: Select from Main Menu
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.66 out of 5.00 points Rating effectiveness M: 4.00 out of 5.00 points **Rating efficiency M: 2.95 out of 5.00 points** Evaluation satisfaction M: 3.60 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.59 out of 5.00 points Rating effectiveness M: 4.06 out of 5.00 points Rating efficiency M: 3.21 out of 5.00 points Evaluation satisfaction M: 3.64 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Select from main menu	Category	Generic task: Select from main menu
Name	Layout variant: Main menu as circle Interaction variant: Interaction through gestures	Name	Layout variant: Main menu as circle Interaction variant: Interaction through focusing
Problem	A range of applications and content is available to the user. For an overview of the different contents, the user needs a main menu. Therefore, the interaction with the main menu is relevant for the user.	Problem	A range of applications and content is available to the user. For an overview of the different contents, the user needs a main menu. Therefore, the interaction with the main menu is relevant for the user.
Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. The main menu in the form of a circle allows the user to see the complete contents of the main menu briefly. With this form of display, interaction via gesture control is suitable. The action is consciously and purposefully triggered by the user through a hand movement. **Attention:** One hand must always trigger the action, which does not allow complete hands-free work.	Solution	The main menu is displayed when the AR terminal is started. The information is available to the user situationally and must be called up specifically. The main menu in the form of a circle allows the user to see the complete contents of the main menu briefly. With this form of presentation, the interaction is suitable by focusing with the eye. In this form of presentation, the interaction is suitable by focusing with the eye. The action is only triggered after a set period and enables complete, hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.72 out of 5.00 points Rating effectiveness M: 3.93 out of 5.00 points **Rating efficiency M: 2.98 out of 5.00 points** Evaluation satisfaction M: 3.73 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.65 out of 5.00 points Rating effectiveness M: 3.99 out of 5.00 points Rating efficiency M: 3.24 out of 5.00 points Evaluation satisfaction M: 3.77 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Deepen object information	Category	Generic task: Deepen object information
Name	Layout variant: Information on the object Interaction variant: Interaction through gestures	Name	Layout variant: Information on the object Interaction variant: Interaction through focusing

Table 13. *Cont.*

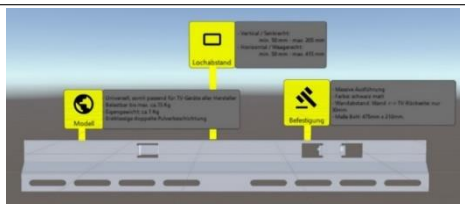
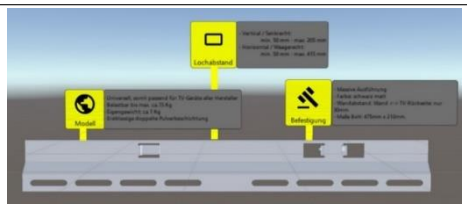
Category	Generic Task: Select from Main Menu	Category	Generic Task: Select from Main Menu
Problem	The user should be shown additional information about a specific object or product. The user should be able to quickly grasp and retrieve this information. The interaction with the main menu is relevant for the user.	Problem	The user should be shown additional information about a specific object or product. The user should be able to quickly grasp and retrieve this information. The interaction with the main menu is relevant for the user.
Solution	For 3D models and objects, additional information can be provided to the user. This can be called up situationally using icons. To place the information in the appropriate place and in the user's field of vision, it is advisable to display the content directly on the object. In this form of presentation, interaction via gesture control is suitable. The user consciously and specifically triggers the action with a hand movement. However, one hand always must trigger the action, which does not allow complete hands-free work.	Solution	For 3D models and objects, additional information can be provided to the user. This can be called up situationally using icons. To place the information in the appropriate place and in the user's field of vision, it is advisable to display the content directly on the object. In this form of presentation, interaction by focusing with the eye is suitable. The action is triggered only after a specified period and enables complete, hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 4.25 out of 5.00 points Rating effectiveness M: 4.31 out of 5.00 points Rating efficiency M: 3.22 out of 5.00 points Evaluation satisfaction M: 4.28 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 4.28 out of 5.00 points Rating effectiveness M: 4.43 out of 5.00 points Rating efficiency M: 3.48 out of 5.00 points Evaluation satisfaction M: 4.33 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Deepen object information	Category	Generic task: Deepen object information
Name	Layout variant: Information far from object Interaction variant: Interaction through gestures	Name	Layout variant: Information far from object Interaction variant: Interaction through focusing
Problem	The user should be shown additional information about a specific object or product. The user should be able to quickly grasp and retrieve this information. The interaction with the main menu is relevant for the user.	Problem	The user should be shown additional information about a specific object or product. The user should be able to quickly grasp and retrieve this information. The interaction with the main menu is relevant for the user.
Solution	For 3D models and objects, additional information can be provided to the user. This can be called up situationally using icons. The information can be bundled in a central location and placed in the user's field of vision; for this purpose, it is advisable to display the content above the object. With this form of presentation, interaction via gesture control is suitable. The action is consciously and purposefully triggered by the user through a hand movement. **Attention:** One hand must always trigger the action, which does not allow complete hands-free work.	Solution	For 3D models and objects, additional information can be provided to the user. This can be called up situationally using icons. The information can be bundled in a central location and placed in the user's field of vision; for this purpose, it is advisable to display the content above the object. In this form of presentation, the interaction is suitable by focusing with the eye. In this case, the action is only triggered after a set period and enables complete, hands-free interaction. **Attention:** The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.

Table 13. *Cont.*

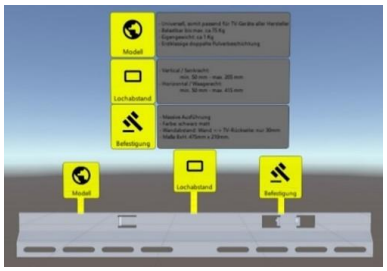
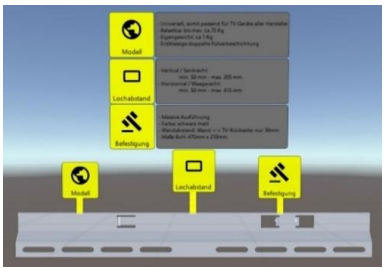
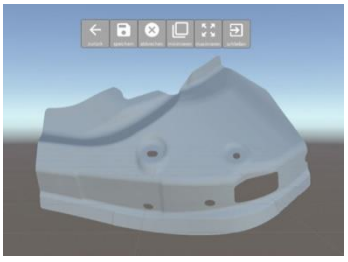
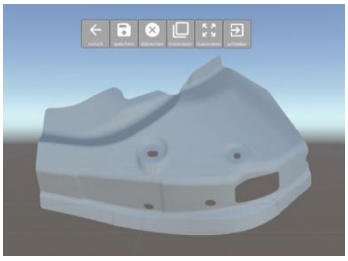
Category	Generic Task: Select from Main Menu	Category	Generic Task: Select from Main Menu
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.45 out of 5.00 points Rating effectiveness M: 3.64 out of 5.00 points **Rating efficiency M: 2.60 out of 5.00 points** Evaluation satisfaction M: 3.52 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.48 out of 5.00 points Rating effectiveness M: 3.76 out of 5.00 points **Rating efficiency M: 2.86 out of 5.00 points** Evaluation satisfaction M: 3.57 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Selecting from the toolbar	Category	Generic task: Selecting from the toolbar
Name	Layout variant: Function bar top Interaction variant: Interaction through gestures	Name	Layout variant: Function bar top Interaction variant: Interaction through focusing
Problem	While the user is in an application, a toolbar is needed so that the current position can be left.	Problem	While the user is in an application, a toolbar is needed so that the current position can be left.
Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar at the top is perceived directly by the user. The function bar can be placed above textual content as well as above graphical elements. In this form of presentation, interaction via gesture control is suitable. The user consciously and specifically triggers the action with a hand movement. However, one hand always must trigger the action, which does not allow complete hands-free work.	Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar at the top is perceived directly by the user. The function bar can be placed above textual content as well as above graphical elements. With this form of presentation, the interaction is suitable by focusing with the eye. In this case, the action is triggered only after a specified period and enables complete, hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.94 out of 5.00 points Rating effectiveness M: 4.14 out of 5.00 points Rating efficiency M: 3.24 out of 5.00 points Evaluation satisfaction M: 3.81 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.83 out of 5.00 points Rating effectiveness M: 4.18 out of 5.00 points Rating efficiency M: 3.44 out of 5.00 points Evaluation satisfaction M: 3.88 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Selecting from the toolbar	Category	Generic task: Selecting from the toolbar
Name	Layout variant: Function bar down Interaction variant: Interaction through gestures	Name	Layout variant: Function bar down Interaction variant: Interaction through focusing
Problem	While the user is in an application, a toolbar is needed so that the current position can be left.	Problem	While the user is in an application, a toolbar is needed so that the current position can be left.

Table 13. *Cont.*

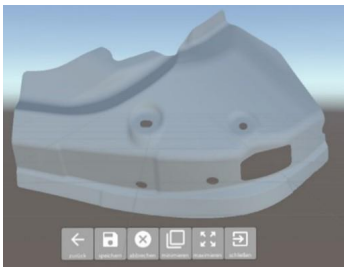
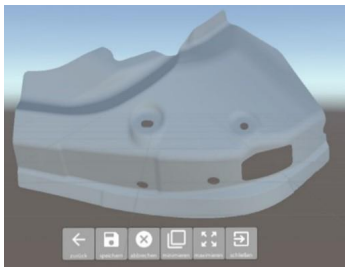
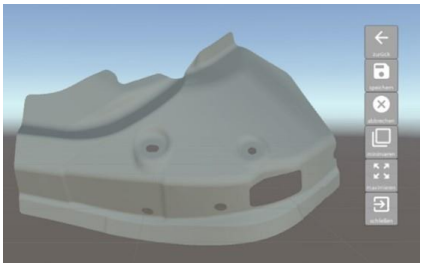
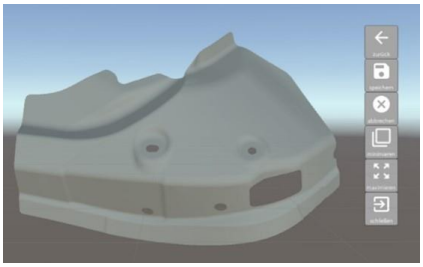
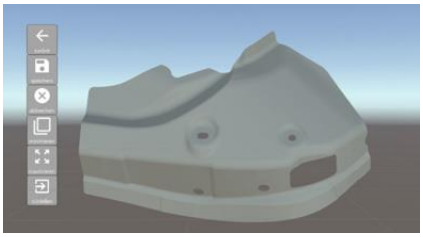
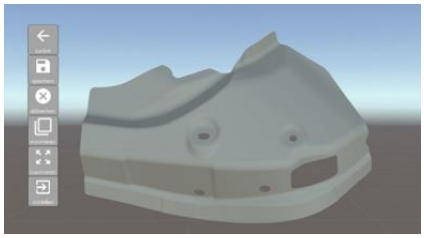
Category	Generic Task: Select from Main Menu	Category	Generic Task: Select from Main Menu
Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar at the bottom is directly perceived by the user. The function bar can be placed under textual content as well as under graphical elements. With this form of presentation, interaction via gesture control is suitable. The user consciously and purposefully triggers the action by moving his or her hand. However, one hand always must trigger the action, which does not allow complete hands-free working.	Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar at the bottom is directly perceived by the user. The function bar can be placed under textual content as well as under graphical elements. In this form of presentation, the interaction is suitable by focusing with the eye. The action is only triggered after a set period and enables complete hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.73 out of 5.00 points Rating effectiveness M: 4.08 out of 5.00 points Rating efficiency M: 3.27 out of 5.00 points Evaluation satisfaction M: 3.61 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.62 out of 5.00 points Rating effectiveness M: 4.12 out of 5.00 points Rating efficiency M: 3.47 out of 5.00 points Evaluation satisfaction M: 3.68 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	
Category	Generic task: Selecting from the toolbar	Category	Generic task: Selecting from the toolbar
Name	Layout variant: Function bar right Interaction variant: Interaction through gestures	Name	Layout variant: Function bar right Interaction variant: Interaction through focusing
Problem	While the user is in an application, a toolbar is needed so that the current position can be left.	Problem	While the user is in an application, a toolbar is needed so that the current position can be left.
Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar on the right-hand side is perceived directly by the user. The toolbar can be placed to the right of textual content as well as to the right of graphical elements. In this form of presentation, interaction via gesture control is suitable. The user consciously and specifically triggers the action with a hand movement. However, one hand always has to trigger the action, which does not allow complete hands-free work.	Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar on the right-hand side is perceived directly by the user. The toolbar can be placed to the right of textual content as well as to the right of graphical elements. With this form of presentation, the interaction is suitable by focusing with the eye. In this case, the action is triggered only after a specified period and enables complete hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unintentional actions can also be triggered in this way.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.75 out of 5.00 points Rating effectiveness M: 4.04 out of 5.00 points Rating efficiency M: 3.02 out of 5.00 points Evaluation satisfaction M: 3.71 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.52 out of 5.00 points Rating effectiveness M: 4.08 out of 5.00 points Rating efficiency M: 3.22 out of 5.00 points Evaluation satisfaction M: 3.78 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)

Table 13. *Cont.*

Category	Generic Task: Select from Main Menu	Category	Generic Task: Select from Main Menu
Representation		Representation	
Category	Generic task: Selecting from the toolbar	Category	Generic task: Selecting from the toolbar
Name	Layout variant: Function bar left Interaction variant: Interaction through gestures	Name	Layout variant: Function bar left Interaction variant: Interaction through focusing
Problem	While the user is in an application, a toolbar is needed so that the current position can be left.	Problem	While the user is in an application, a toolbar is needed so that the current position can be left.
Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar in the left area is perceived directly by the user. The toolbar can be placed to the left of textual content as well as to the left of graphical elements. With this form of presentation, interaction via gesture control is suitable. The user consciously and purposefully triggers the action by moving his or her hand. However, the action must always be triggered by one hand, which does not allow complete hands-free working.	Solution	The function bar has the task in the AR system that the user can navigate in the current view. As soon as an activity is selected from the main menu, the function bar is permanently available to the user. The function bar in the left area is perceived directly by the user. The toolbar can be placed to the left of textual content as well as to the left of graphical elements. In this form of presentation, the interaction is suitable by focusing with the eye. The action is only triggered after a set period and enables complete hands-free interaction. The time span until the interaction is triggered should only last a few seconds in order not to influence the daily work routine; however, unwanted actions can also be triggered in this way.
Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.63 out of 5.00 points Rating effectiveness M: 3.97 out of 5.00 points Rating efficiency M: 3.11 out of 5.00 points Evaluation satisfaction M: 3.44 out of 5.00 points	Evidence	Usability test: Prototypical evaluation with 50 test persons Evaluation of usefulness M: 3.52 out of 5.00 points Rating effectiveness M: 4.01 out of 5.00 points Rating efficiency M: 3.31 out of 5.00 points Evaluation satisfaction M: 3.51 out of 5.00 points
(. . .)	(. . .)	(. . .)	(. . .)
Representation		Representation	

6. Discussion

The paper aims to draw attention to the importance of layout design in the industrial sector. However, this is only the first step, and investigations are still very general.

From the point of view of software technology, many further developments can still be included over the next few years. Long-term ergonomic studies are still required for the permanent use of data glasses. These can look at the effects of permanent use of the data devices in the workplace for employees and include occupational health and safety. The present paper is still general in its industrial orientation. Here, too, subsequent studies can deal more intensively with the industry-specific subtasks. Especially in the layout design, differentiation is important for the coming years so that there are explicit ways of

looking at the different workflows and tasks. In addition to the layout, other interaction possibilities must always be considered. Gesture control is always developed further and here, it requires an iterative review as to which interactions are applicable in the industrial field. This paper is intended to be the initial impetus for further investigations and would like to focus on industry in the technical developments.

7. Conclusions

The background of the paper is the processing of data from Industry 4.0 in quality assurance with AR glasses. The research objective is to explore how the user interface of an AR system can be designed in an industrial environment. The goal is to create a standard on a high ergonomic level that makes it possible to create consistency between AR applications. The experiment results showed that there is no difference in the ergonomic quality of the four de facto standards on the market in terms of layout. However, in terms of interaction, focusing was preferred over gesture control. This led to the finding that the solutions on the market already have a certain ergonomic quality that has grown over time. No clear preferences could be found among users regarding the layout design. The limitations lie in reducing the information to fit the task and context. The pattern catalog is intended to serve as the first aid for developers when designing user interfaces for AR end devices in the industrial sector. Furthermore, the paper provides a starting point for future research. Recognizing decision patterns is important, which can be achieved by combining information technologies, such as business and operational intelligence.

Author Contributions: Writing—original draft, R.K.; writing—review & editing, H.K. All authors have read and agreed to the published version of the manuscript.

Funding: AssiQ Assistance system for quality monitoring; Duration: 1 May 2017 to 31 October 2019, Project funding: Federal Ministry of Education and Research.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: There is no conflict of interest.

References

1. Plutz, M.; Große Böckmann, M.; Siebenkotten, P.; Schmitt, R. *Smart Glasses in der Produktion: Studienbericht des Fraunhofer-Instituts für Produktionstechnologie IPT*; Fraunhofer: Munich, Germany, 2016; pp. 16–21.
2. Dey, A.; Billinghurst, M.; Lindeman, R.W.; Swan, J.E., II. A Systematic Review of Usability Studies in Augmented Reality between 2005 and 2014. In Proceedings of the 2016 IEEE International Symposium on Mixed and Augmented Reality, Merida, Yucatan, Mexico, 19–23 September 2016; Veas, E., Langlotz, T., Martinez-Carranza, J., Grasset, R., Sugimoto, M., Eds.; IEEE: Piscataway, NJ, USA, 2016; pp. 49–50. [CrossRef]
3. Koreng, R. AR in production: Development of UI patterns. In Proceedings of the Mensch und Computer 2019 on—MuC'19, Mensch und Computer 2019, Hamburg, Germany, 8–11 September 2019; Alt, F., Bulling, A., Döring, T., Eds.; ACM Press: New York, NY, USA, 2019; pp. 658–659. [CrossRef]
4. Ehrlenspiel, K.; Meerkamm, H. *Integrierte Produktentwicklung. Denkabläufe, Methodeneinsatz, Zusammenarbeit*, 5th ed.; Hanser: München, Germany, 2013; pp. 312–317.
5. Karl, D.E.; Soderquist, K.A.; Farhi, M.; Grant, A.H.; Pekarek Krohn, D.R.; Murphy, B.; Schneiderman, J.; Straughan, B. *2018 Augmented and Virtual Reality Survey Report: Industry Insight into the Future of AR/VR*; Perkins Coie LLP: Seattle, WA, USA, 2018.
6. Takatsu, Y.; Saito, Y.; Shiori, Y.; Nishimura, T.; Matsushita, H. Key Points for Utilizing Digital Technologies at Manufacturing and Maintenance Sites. *Fujitsu Sci. Tech. J.* **2018**, *54*, 9–15.
7. Billinghurst, M.; Clark, A.; Lee, G. A Survey of Augmented Reality. In *Foundations and Trends® in Human–Computer Interaction*; Alet Heezemans: Delft, The Netherlands, 2015; Volume 8, pp. 73–272. [CrossRef]
8. Nilsson, E.G. Design patterns for user interface for mobile applications. *Adv. Eng. Softw.* **2009**, *40*, 1318–1328. [CrossRef]
9. Oscar, D.; Magnus, H.; Anna, S. Augmented Reality Smart Glasses for Industrial Assembly Operators: A Meta-Analysis and Categorization. *Adv. Transdiscipl. Eng.* **2019**, *9*, 173–179.

10. Bowman, D.A.; Krujiff, E.; LaViola, J.J., Jr.; Poupyrev, I. *3D User Interfaces. Theory and Practice*; Addison-Wesley: Boston, MA, USA, 2005; pp. 6–8, 139–181, 255–285, 313–347.
11. LaViola, J.J., Jr.; Kruijff, E.; McMahan, R.P.; Bowman, D.A.; Poupyrev, I. *3D User Interfaces. Theory and Practice*; Addison-Wesley: Boston, MA, USA, 2017; pp. 6–8, 18–19, 144–146, 258, 255–311, 379–413, 421–451.
12. DIN Deutsches Institut für Normung e.V. *Ergonomie der Mensch-System-Interaktion—Teil 110: Grundsätze der Dialoggestaltung*; ICS 13.180; 35.080; 35.240.20, DIN EN ISO 9241-110; Beuth Verlag GmbH: Berlin, Germany, 2008.
13. Jerald, J. *The VR Book. Human-Centered Design for Virtual Reality*; ACM: New York, NY, USA; San Rafael, CA, USA, 2016; pp. 441–442.
14. Preim, B.; Dachselt, R. *Interaktive Systeme. Band 2: User Interface Engineering, 3D-Interaktion, Natural User Interfaces*, 2nd ed.; Springer: Berlin/Heidelberg, Germany, 2015; pp. 45–108.
15. Cohé, A.; Dècle, F.; Hachet, M. tBox: A 3D Transformation Widget designed for Touch-screens: CHI'11. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Vancouver, BC, Canada, 7–12 May 2011; pp. 3005–3008.
16. DIN Deutsches Institut für Normung e.V. *Ergonomie der Mensch-System-Interaktion—Teil 400: Grundsätze und Anforderungen für Physikalische Eingabegeräte*; DIN EN ISO 9241-400; Beuth Verlag GmbH: Berlin, Germany, 2007.
17. Dörner, R.; Broll, W.; Grimm, P.; Jung, B. (Eds.) *Virtual und Augmented Reality (VR/AR). Grundlagen und Methoden der Virtuellen und Augmentierten Realität*; Springer Vieweg: Berlin, Germany, 2013.
18. Endsley, M.R.; Jones, D.G. *Designing for Situation Awareness. An Approach to User-Centered Design*, 2nd ed.; CRC Press: Boca Raton, FL, USA, 2012.
19. Friedrich, W. ARVIKA-Augmented Reality for Development, Production and Service. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.194.6733&rep=rep1&type=pdf (accessed on 31 May 2017).
20. Gabbard, J.L. Researching Usability Design and Evaluation Guidelines for Augmented Reality (AR) Systems. Available online: http://www.rkriz.net/sv/classes/ESM4714/Student_Proj/class00/gabbard/index.html (accessed on 31 May 2017).
21. Kratz, S.; Rohs, M.; Guse, D.; Müller, J.; Bailly, G.; Nischt, M. PalmSpace: Continuous Around-Device Gestures vs. Multitouch for 3D Rotation Tasks on Mobile Devices: AVI 12. In Proceedings of the International Working Conference on Advanced Visual Interfaces, Capri Island (Naples), Italy, 22–25 May 2012; pp. 181–188.
22. Reisman, J.L.; Davidson, P.L.; Han, J.Y. A Screen-Space Formulation for 2D and 3D Direct Manipulation: UIST'09. In Proceedings of the 22nd Annual ACM Symposium on User Interface Software and Technology, Victoria, BC, Canada, 4–7 October 2009; pp. 69–78.
23. Theis, S.; Pfendler, C.; Alexander, T.; Mertens, A.; Brandl, C.; Schlick, C.M. *Head-Mounted Displays—Bedingungen des Sicheren und Beanspruchungsoptimalen Einsatzes: Physische Beanspruchung beim Einsatz von HMDs*; Bundesanstalt für Arbeitsschutz und Arbeitsmedizin: Dortmund, Germany, 2016; ISBN 978-3-88261-162-5.
24. Aragon, C.R.; Hearst, M.A. Improving Aviation Safety with Information Visualization: A Flight Simulation Study. In Proceedings of the CHI'05: SIGCHI Conference on Human Factors in Computing Systems, Portland, OR, USA, 2–7 April 2005; ACM: New York, NY, USA, 2005.
25. DIN Deutsches Institut für Normung e.V. *Ergonomische Anforderungen für Bürotätigkeiten mit Bildschirmgeräten—Teil 13: Benutzerführung*; DIN EN ISO 9241-13; Beuth Verlag GmbH: Berlin/Heidelberg, Germany, 2000.
26. DIN Deutsches Institut für Normung e.V. *Ergonomie der Mensch-System-Interaktion—Teil 154: Sprachdialogsysteme*; DIN EN ISO 9241-154; Beuth Verlag GmbH: Berlin/Heidelberg, Germany, 2013.
27. Ong, S.K.; Nee, A.Y.C. *Virtual and Augmented Reality Applications in Manufacturing*; Springer: London, UK, 2004; pp. 129–183.
28. Schinke, T.; Henze, N.; Boll, S. Visualization of off-screen objects in mobile augmented reality. In Proceedings of the 12th International Conference on Human Computer Interaction with Mobile Devices and Services, Lisbon, Portugal, 7–10 September 2010; ACM: New York, NY, USA, 2010; pp. 313–316.
29. Schmitt, M.; Zühlke, D. Smartphones und Tablets in der industriellen Produktion: Nutzerfreundliche Bedienung von Feldgeräten. *Autom. Prax.* **2013**, *55*, 58. [CrossRef]
30. Uratani, K.; Machida, T.; Kiyokawa, K.; Takemura, H. A study of depth visualization techniques for virtual annotations in augmented reality. In Proceedings of the IEEE Virtual Reality 2005, Bonn, Germany, 12–16 March 2005; Fröhlich, B., Ed.; IEEE Service Center: Piscataway, NJ, USA, 2005; pp. 295–296. [CrossRef]
31. Diepstraten, J.; Weiskopf, D.; Ertl, T. Interactive Cutaway Illustrations. *Comput. Graph. Forum* **2003**, *22*, 523–532. [CrossRef]
32. DIN Deutsches Institut für Normung e.V. *Ergonomische Anforderungen für Bürotätigkeiten mit Bildschirmgeräten—Teil 16: Dialogführung Mittels Direkter Manipulation*; DIN EN ISO 9241-16; Beuth Verlag GmbH: Berlin/Heidelberg, Germany, 2000.
33. Hashemian, A.M.; Riecke, B.E. Leaning-Based 360° Interfaces: Investigating Virtual Reality Navigation Interfaces with Leaning-Based-Translation and Full-Rotation. In *Virtual, Augmented and Mixed Reality, Proceedings of the 9th International Conference, VAMR 2017, Held as Part of HCI International 2017, Vancouver, BC, Canada, 9–14 July 2017*; Lackey, S., Chen, J., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 15–32.
34. Preim, B.; Dachselt, R. *Interaktive Systeme. Band 1: Grundlagen, Graphical User Interfaces, Informationsvisualisierung*, 2nd ed.; Springer: Berlin/Heidelberg, Germany, 2010; pp. 245–281.
35. Pohl, C.; Waßmann, H. *Wahrnehmungsgerechte Präsentati Wahrnehmungsgerechte Präsentation von Designentwürfen mit Hilfe von Augmented Reality*; ViProSim-Paper; OWL ViProSim e.V.: Paderborn, Germany, 2009; pp. 405–419.

36. Cooper, A.; Reimann, R.; Cronin, D.; Engel, R. *About face. Interface und Interaction Design*; Mitp-Verlag: Heidelberg/Hamburg, Germany, 2010; pp. 77–88, 98.
37. Pruitt, J.S.; Adlin, T. *The Persona Lifecycle. Keeping People in Mind Throughout Product Design*; Elsevier: Amsterdam, The Netherlands; Boston, MA, USA, 2006; pp. 11, 230–232.
38. Miaskiewicz, T.; Kozar, K.A. Personas and user-centered design: How can personas benefit product design processes? *Des. Stud.* **2011**, *32*, 417–430. [CrossRef]
39. Mayas, C.; Hörold, S.; Krömker, H. (Eds.) *Personas for Requirements Engineering. Opportunities and Challenges*; Springer: Berlin/Heidelberg, Germany, 2016.
40. Steinert, T.; Koreng, R.; Mayas, C.; Cherednychek, N.; Dohmen, C.; Hörold, S.; Krempels, K.-H.; Kehren, P. Offene Mobilitätsplattform (OMP): Teil 1: Rollenmodell & Typische Kooperationsszenarien. VDV-Schriftem 436-1; August 2019. Available online: http://docplayer.org/178259330-Vdv-schrift-2019-offene-mobilitaetsplattform-omp-teil-1-rollenmodell-typische-kooperationsszenarien.html (accessed on 10 June 2021).
41. Koreng, R. *Entwicklung Eines Patternkatalogs für Augmented Reality Interfaces in der Industrie*; Universitätsverlag Ilmenau: Ilmenau, Germany, 2021.
42. Alexander, C.; Ishikawa, S.; Silverstein, M.; Jacobson, M. *A Pattern Language. Towns, Buildings, Construction*, 41st ed.; Oxford University Press: New York, NY, USA, 1977; pp. ix–xvii.
43. Mahemoff, M.J.; Johnston, L.J. Principles for a usability-oriented pattern language. In Proceedings of the 1998 Australasian Computer Human Interaction Conference, OzCHI'98, Adelaide, SA, Australia, 30 November–4 December 1998. [CrossRef]
44. van Duyne, D.K.; Landay, J.A.; Hong, J.I. *The Design of Sites. Patterns, Principles, and Processes for Crafting a Customer-Centered Web Experience*, 6th ed.; Addison-Wesley: Boston, MA, USA, 2005; pp. 18–30.
45. Kunert, T. *User-Centered Interaction Design Patterns for Interactive Digital Television Applications*; Springer: London, UK, 2009; pp. 58–60, 142–144.
46. Lindemann, U. (Ed.) *Handbuch Produktentwicklung*; Hanser: München, Germany, 2016.
47. Koreng, R.; Krömker, H. Augmented Reality Interface: Guidelines for the Design of Contrast Ratios. In Proceedings of the ASME 2019 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Anaheim, CA, USA, 18–21 August 2019; American Society of Mechanical Engineers: New York, NY, USA, 2019. [CrossRef]
48. DIN Deutsches Institut für Normung e.V. *DIN EN ISO 9241-11: 2018-11, Ergonomie der Mensch-System-Interaktion_-Teil_11: Gebrauchstauglichkeit: Begriffe und Konzepte (ISO_9241-11:2018)*; Deutsche Fassung EN_ISO_9241-11:2018; Beuth Verlag GmbH: Berlin, Germany, 2018.