

Visualizing Ergonomic Data of Industrial Work Processes: A Design Study

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Abstract: Ergonomics deals with the analysis and design of work processes. To identify ergonomically critical situations, appropriate evaluation options have to be developed to enable an efficient analysis process. Nowadays, such analyses are typically carried out with the help of digital models of the surrounding area and virtual humans. These produce a multitude of geo-referenced and time-oriented data. We present a design study on how to visualize this data to support the ergonomically analysis process optimally. As consequence of a thorough requirements analysis and design process, we propose a novel interactive visualization which provides the user an overview of ergonomically critical situations and their causes. Simultaneously, the user obtains the main stress factors in a compressed form by a glyph-based visual design. Final expert interviews and a usability study depict the utility of the proposed visualization tool.

1 INTRODUCTION

For a few years, the scientific institute of the German health insurance AOK (WIdO) (Zok, 2010) performed an employee survey in 147 German companies about health disorders and workload. In total, more than 28,000 people were surveyed in companies with a size between 35 and 2,252 employees. When asked, “What do you find more important for your health” 55 percent of the respondents answered (after enough sleep and a balanced diet) that healthy working conditions are decisive. Many employees suffer under heavy physical work. This includes particularly heavy loads as “lift and carry”. Thus, there is generally a need for action to improve the employment situation in the companies. Especially ergonomists deal with the elimination of bad work situations. They examine the work, take measurements, and analyze the data obtained. According to the analysis they present their findings to third parties, for example to the management.

In this regard, studies of longer periods (an entire shift or several working cycles) can lead to a huge amount of data and complex structures. Thus, the evaluation of the values obtained and the presentation towards the authorities concerned can be very challenging. However, satisfactory visualizations are currently still rare and often limited to simple line or bar

charts. In a previous publication (Heft et al., 2015), we presented an user-interaction concept and first preliminary designs to visualize ergonomic data. In this paper, we present a thorough design study and investigate how an interactive visualization could lead to a facilitation of the evaluation work of ergonomists. At first, we performed a requirements analysis in cooperation with real ergonomists and with the help of everyday use cases from real work places, see Section 2. Afterwards, we performed an iterative design process on basis of the gathered requirements, leading to a working prototype, see Section 5. Finally, we conducted a user study with different usergroups (ergonomists and laymen) to valuate the usability and benefit of this interactive visualization, see Section 6.

2 REQUIREMENT ANALYSIS

For obtaining a human-centered visual design, a description of user context and user requirements has to be made. In order to analyze the user context it is necessary to record user characteristics, work tasks, and framework conditions.

We obtained these insights by means of workshops (in two German companies) with ergonomists and occupational health and safety practitioners (in total seven experts). We used the method “focus

group” (Courage and Baxter, 2005, pp. 25ff), i.e., we presented our questions to groups of experts. We discussed the steps of the requirements analysis in detail in Heft et al. (Heft et al., 2015).

We summarize its results below:

The user’s task

The ergonomists have the task of analyzing and improving the technical, organizational, and social conditions of work processes. For this purpose data needs to be collected, evaluated, and transferred into adequate solutions. Furthermore, their outcomes will be presented to the management or to the worker.

Requirements

- an easy-to use program
 - interactive explanations on all displayed elements
 - detailed information about the analyses should be easily obtainable (if required)
- intuitive and sustainable data representation
 - understandable to non-experts
 - fast overview of all ergonomic problems over time
 - falling above/below limit values should be visible at a glance
 - color coding, instead of tabular form
 - simple images for presentation
 - video to show the workers the work flow
- hardware requirements
 - executable on standard PCs

Data to be visualized

- posture
- time of occurrence
- duration of a ergonomically critical situation
- score of the different evaluation methods
- reasons for an issue, such as the weight of a carried object
- additional variables, for instance, the body joint angles as well as their limit values

3 STATE OF THE ART

The presentation of ergonomic results is often bound to lists, simple graphical dialogs, and graphs. The most popular representations of ergonomic reports for RULA (McAtamney and Nigel Corlett, 1993) originate from the digital human models (DHM) “Human Builder” (Dassault Systèmes) and “Jack” (Siemens). In either case, they based on a straightforward tabular

form. Their views show the ratings of the individual body parts (e.g. for the upper arm, neck, and legs), the force and load values, and the total number of points of the pose (incl. a color coding in the traffic light scheme). “Dynamicus” (Institut für Mechatronik e.V., 2016) is an example of an ergonomic report, which represent the results of the EAWS method (Schaub et al., 2013) in a DHM. Here, the representation of the time component is incorporated. It indicate the pose through a rotatable DHM, duration, partial evaluations, and the total score of the analysis, for example. Bad poses are notified over a gantt chart.

The programs, however, are not fully capable to comply with the desired user requirements. First, there is no way to change the depth of analysis. On the other hand, only a static pose can be displayed, instead of a complete overview of all problems. Visual analysis of the data by zoom and filter mechanisms is often not supported. Moreover, the problems are always displayed for a single method of analysis. This means, that possible interrelated causes cannot be perceived.

4 RELATED WORK

Since time-oriented data is relevant in many practical situations, the visualization of such data is ubiquitous. Many recent work exists (Aigner et al., 2011), (Silva and Catarci, 2000), (Tominski and Aigner, 2015). However, visualizations in digital human models for showing critical ergonomic situations or illustrating time-oriented processes are very limited.

The concept of timelines for time-oriented data is used in LifeLines (Plaisant et al., 1996). LifeLines was developed to create an overview about certain events in the life of a person. Because of the presences of all import information at one stage, the doctors can provide a better prognosis about the medical condition.

However, an overview for a mass of data can quickly lead to confusion. LifeFlow (Wongsuphasawat et al., 2011) delivers a possibility to counteract this circumstance with event sequences (series of temporal distinct and consecutive events). In connection to the aforesaid work (LifeLines), individual data records can be displayed with much more detail.

In order to perform a performance analysis in real-time sports events (e.g., rugby or football), videos are annotated by analyst teams. However, this leads to a large amount of statistics or tables with many data records. It would be almost impossible for a trainer to capture this data in real time. Thus, important details could easily be overlooked. Matchpad (Legg et al.,

2012) provides a solution by means of a glyph-based overview visualization. Kicks, a line out, or referee events are displayed on a time scale in real time.

Timelines are mostly used for the visualization of time-oriented data. These often begin on the left side and run horizontally to the right side (as LifeLines or programs for editing and displaying video and audio files). However, this is not always necessary. For example the VisRuption project (Rosenthal et al., 2013) facilitates timelines that run from the bottom to the top.

The above listed publications provide approaches and ideas for this work. However none of the existing work corresponds to the user requirements of an interactive visualization for an overview display of ergonomic problems.

5 DESIGN PROCESS

The designing of the workable visualization was done on basis of the user requirements and iterative prototyping. During the implementation, the current state was discussed with the experts in several meetings. Some errors in the design and programming were discovered and subsequently removed. New enhancements were proposed and integrated into the program. C++ and Qt was used to create the software.

The functional parts of the GUI are shown in Figure 1. It can be divided into two main sections. The upper part provides a quick overview and is divided into three levels, such as the display of selected critical situations as pictograms, the total scores of selected problems per analysis method, and a timeline with all ergonomic problems. The lower part provides opportunities for detailed analysis with a video-view and a display, which may include detailed information about calculations and other results. A help button is located at the right edge of each level. The help describes the elements, and the interaction of the respective level.

5.1 Pictogram Level

The pictograms of the five currently selected ergonomically critical situations are shown on the first level (see Fig. 1, pictogram level). The presentation symbolizes bad poses, impairments by noise, etc. The problem can be selected by a click on a pictogram. This selection leads to two reactions, an optical and a functional.

Optical: The problem is shown with a gray background (see Fig. 1, the centrally positioned problem). The background stretches over the correspond-

ing evaluation points (see Sec. 5.2) of the selected problem and ends at the problem position on the timeline (see Sec. 5.3). This is intended to help the user to keep the data of a critical situation, across all levels, in mind.

Functional: By selecting a problem, the appropriate video sequence shows the current problem in a loop (see Sec. 5.4). In addition, the corresponding calculation details are displayed. Additional information can be attached to the right of a pictogram. They are intended to provide information about the reasons for a poor assessment, such as a carried (heavy) weight or an excessively bent body. Besides the symbolic representation, the user receives the exact values via tooltip. Directly below a pictogram, there is a stopwatch symbol and the duration of a single action. The distance line between two pictograms is labeled with the duration from the end of an action to the beginning of the following problem. If more than five problems are selected in the timeline, the arrows on the left and right of the pictogram bar allow a navigation. By means of a mouse click, additional problems can be displayed. There are two arrows on each side: A simple arrow is used to move one problem at a time, the double arrow shows the next five problems. The former makes it possible to compare problems that occur in succession but are not presented in the view. The double arrow allows faster selection of all selected problems, so the next five are displayed. Between the two arrows, the number of the following resp. preceding cases is given.

5.2 Assessment Level

On the second level (see Fig. 1, assessment level), the total score points for each analysis method (e.g. RULA, EAWS, noise and climate) are shown for the displayed five problems. The results are structured in tabular form. Each row contains the values of a analysis method. The method is indicated at the beginning of each row. This allows a comparison of all values over time. The first column of a table (located below a pictogram) indicates the severity of a problem by color coding. The red color symbolizes a very high-risk problem and improvements should be made immediately. Orange represents an intermediate risk and changes should be made soon. A low risk is expressed by yellow. If there is no risk, white is used for the corresponding evaluation method. This was implemented in contrast to the original color coding (green), due to the reasons mentioned in Section 5.5. A click on the color field selects the problem and marks it with a gray background as explained in the description of pictogram level. Furthermore, it will

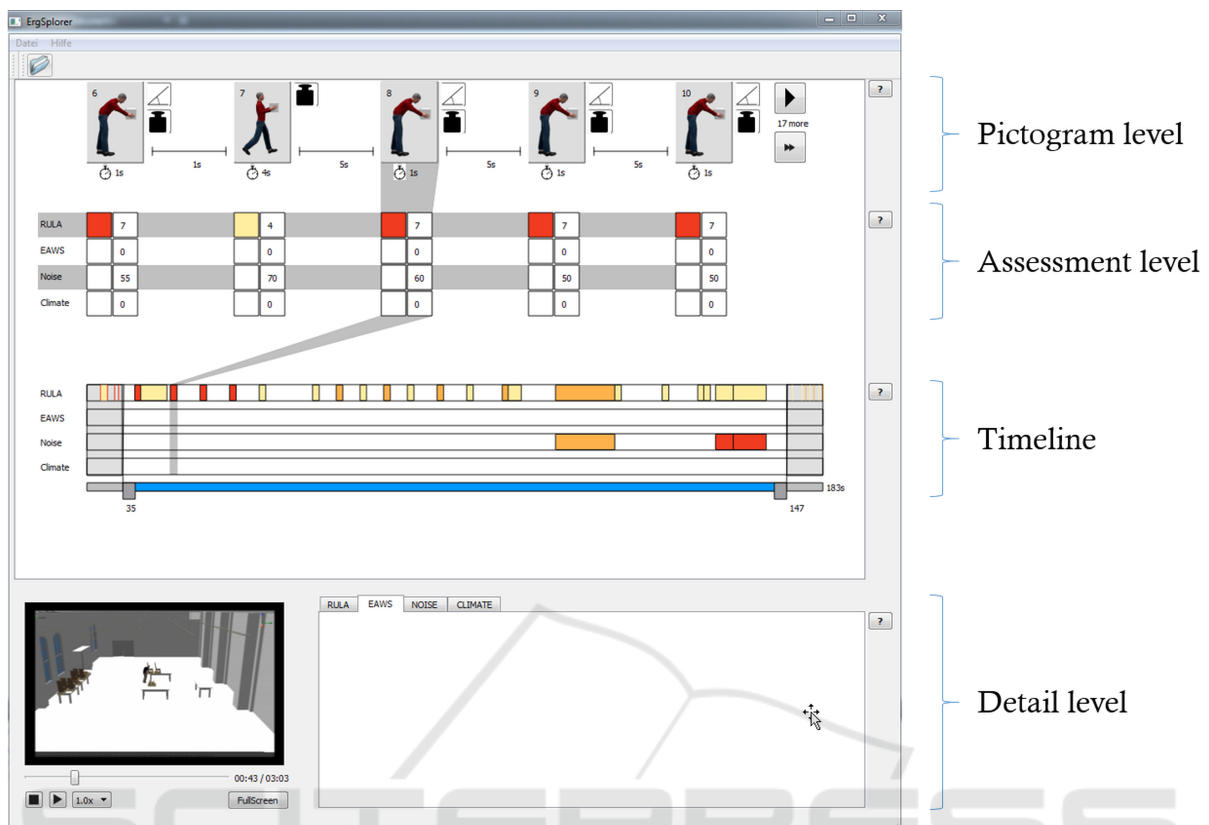


Figure 1: The implemented interactive visualization with a chosen area on the timeline and a selected problem. The pictogram level symbolizes the reasons of the problems. The assessment level shows the overall scores of the corresponding analysis. The severity of the problem is color coded. The third level (timeline) contains selectable bars. The bars starts at the position relative to the real time. The length corresponds to the duration of the problem and the color to its severity. The detail view encloses a video and space for further informations.

open the corresponding tab in the detailed view (see Sec. 5.4). For example, if the user clicks on a color field in the “noise” row, the noise tab is automatically selected in the detail view. The second column of a table contains the total points of an analysis.

5.3 Timeline

A timeline is depicted on the third level (see Fig. 1, timeline). The colored bars symbolize the ergonomic problems. The beginning of a bar starts at the position relative to the real time. The length corresponds to the duration of the problem and the color to its severity. The problem can be selected by a click on the bar. This displays the corresponding details in the other levels (pictogram, assessment, detail). The critical cases are listed in rows for each analysis method. Below the timeline is a slider. At the right end, the total time is indicated in seconds. Two controllers are located on the slider. A certain time range can be chosen by setting the respective controller to the

desired position. The current position is located directly below the controllers. A vertical auxiliary line is located on each controller over the entire height of the timeline. This allows a precise positioning of the controllers (e.g., directly before or after a problem). The start time of a problem can also be determined via tooltip. If a time period has been selected, the inside area is zoomed in. The bars and the time are increased in proportion. All problems before and after the selected time period are collapsed by compressing the time and the bars. In order to highlight the area of interest, the external problem areas are grayed out.

5.4 Detail Level

On the detailed view (see Fig. 1, detail level) there is a video and a detail representation. In the normal state, the video shows automatically the sequence of the currently selected problem in a loop. The “FullScreen” button opens the video in full screen. The “Esc” key or a double-click terminates the full

screen mode. Pressing the stop button closes the video and sets it to the beginning. By pressing the play button, the entire workflow can be viewed from start to end. A slider below the video shows the current position/time (as well as the total time) and allows the user a navigation (forward / backward) within the displayed animation. The contents of the detailed view are not implemented in this work, but are intended to provide the exact values for each analysis. This means that the intermediate results (which contribute to the overall score of each valuation method) can be selected and displayed via the already available tabs.

5.5 Color Selection

In the field of ergonomics, the results are preferably visualized in the traffic light scheme (green, yellow, occasionally additional orange, and red). First, it may be useful to maintain the domains-specific design guidelines in terms of the recognition value. However, we avoided a “red-green”-visualization for two reasons:

1. Red-green weakness: About eight percent of the European males are affected. The corresponding colors cannot be perceived correctly.
2. Show only problems: The core task of the ergonomists is to examine the most dangerous activities and to improve their execution. Using green in the visualization for uncritical situations can lead to an overloading of the overview and a distraction from interesting points.

Instead, we have chosen to indicate the problems with a color coding that changes from yellow to red. All non-problematic time points are colorless or white.

6 EVALUATION

As the final step of our design study, we have evaluated the prototype. In the following, we describe the procedure and the results of our user study.

6.1 Methodology

6.1.1 Study Design

We decided to do a qualitative evaluation. This has two advantages. On the one hand the users' thoughts and feelings can be assessed in more detail. This is an important quality in order to understand the users experience. On the other hand is this approach more explorative. This is an important quality, because it is

impossible to know about the specific problems that will occur during the study in advance. To ensure that the functionality of the prototype was discovered by the test persons, a set of tasks was given to them. They were told to follow the “think aloud” approach during the test of the visualization, in order to get a deeper understanding of their thoughts and feelings. Thus, we had the chance to understand the users experience and the reasons for their problems.

We used the standard norm of “EN ISO 9241-110” for our evaluation, which defines aspects of good dialogues (DIN, 2010):

- suitability for the task,
- suitability for learning,
- suitability for individualization,
- conformity with user expectations,
- self descriptiveness,
- controllability, and
- error tolerance.

These aspects, as well as the readability, may give hints on potential sources of problems. Thus, we wanted to have another measurement for these aspects and introduced an additional questionnaire. The evaluation was complemented by an interview, that gave the chance to get detailed information on specific problems. The prototype was tested in a laboratory study. This allows a calibration of the soft- and hardware and a controlled surroundings. Observations with “pen and paper” and video recording were done.

6.1.2 Participants

According to Nielsen (Nielsen, 2016) 5 participants are sufficient for a qualitative study. Additional participants would encounter almost the same usability problems. Several groups of highly distinct users need 3-4 users from each category. This study included two categories of users:

- 3 experts on ergonomics
- 4 non-experts

The group of experts was chosen in order to ensure the relevance of the visualization in practice and its suitability to the ergonomists. On the other hand, the tool should also be intuitively comprehensible to non-experts, like managers or small companies, that have no ergonomist.

6.1.3 Test Setup

The study took place in a separated room. The observer and the participant were present. The proto-

type ran on a standard laptop (Windows). The visualization was shown on a 22" display. Interaction devices have been a standard mouse and keyboard. Each session lasted at most one hour and consisted of a briefing, the usability test, answering the questionnaire, and an interview.

6.1.4 Briefing

The briefing consisted of an information about the legal and ethical aspects of the study, as well as a standardized explanation of the "think aloud" approach and the prototype. At this point the subject had the chance to ask questions.

6.1.5 Tasks

The tasks were given to the subject in order to test whether he finds the needed functionality, whether understands the visualization, and how much time he needs. The scenario data was based on a simulation program of industrial work processes (Müller et al., 2014). The scenario was manually analyzed in matters of different ergonomic assessments and the critical problems were added to the scenario data. The following tasks should be processed while using the visualization:

- How many highly critical problems occur? (every analysis methods)
- Is there a period of time wherein an increased number of highly critical problems occur? Which one?
- When and where do noise problems occur?
- Describe the two problems between seconds 87 and 95!
 - How severe are these problems? (your subjective impression)
 - What are their values? (every analysis method)
 - If there is any bending in the upper part of the body: what is the angle of the bending?
 - If the workman has an object in his hand: What is its weight?
 - What is the workman doing at this moment?

The relevance of the tasks to the ergonomists work was confirmed by some experts.

6.1.6 Questionnaire

Afterwards, the participants were confronted with a questionnaire, which consisted of 14 questions (VBG, 2016) that tested for the aspects of software ergonomics as stated in Section 6.1.1. The answering

of the questionnaire took about 10 minutes. The answers were given in German grades (1 - very good, 2 - good, ..., 6 - insufficient).

6.1.7 Analysis

Finally the qualitative data (the observers notes, video recordings, interview notes and the free comments from the questionnaire) was coded and categorized. We did an open coding and used an affinity diagram (Courage and Baxter, 2005, pp. 715ff) as method for categorization. Several researchers were involved in the analysis process in order to ensure objectivity. The analysis of the questionnaires included the computation of the arithmetic means, thus giving a tendency on the fulfillment of the ergonomic aspects.

6.2 Results and Discussion

Altogether, every participant was able to solve the given tasks with the help of the prototype. Hence, its effectivity was verified. The time needed for solving the tasks was between 14 and 39 minutes (without briefing, questionnaire, and interviews). Each subject that needed more than twenty minutes for solving the tasks, did a very detailed description of the prototype. The study revealed advantages and disadvantages of the interactive visualization. First we specify the advantages and disadvantages of the overall picture of the visualization. Afterwards, we concentrate on single elements. The latter advantages and disadvantages can be categorized in:

- recognizing the functionality of the interactive elements
- perception of time segments
- getting an overview of the situation
- detailed analysis of ergonomic problems

6.2.1 Overall Picture

The overall tool was helpful in solving the tasks at hand. All possibilities of interaction were detected by the users. At the same time they considered the handling as complex, especially for inexperienced users. The selection of single problems was denoted as intuitive. The characteristics, that had some influence are listed below:

Starting the Tool: Before examining ergonomic analyses, the data has to be loaded. Most of the test persons did this very intuitively, but one was somehow confused. The subject tried to load the data by pressing the play button of the video player. Another subject proposed to show a start

screen with some hints on the first steps, e.g. on how to load the data.

Help: The help buttons seemed to be hard to see. Two participants proposed to position help elements directly at the place that requires it. However, showing a help as tooltips next to the elements, may interfere with the work flow, e.g. if they appear while they are not needed. Thus, we should realize this direct help conditionally. Then, the user would be able to switch this functionality on or off.

Layout: One of the subjects addressed the white space. He suggested to use it to show additional information about the problems. This may cause an even more complex visualization. Furthermore, the test persons experienced the layout as unbalanced. This appeared especially when less than five problems were selected, that caused the disappearing of the buttons for choosing the next five problems and, thus, the timeline was longer than the line of pictograms. In order to align these elements the buttons should rather be masked than disappeared.

Colors: The color coding was well understood by the test persons. Nevertheless, one subject wanted to have a different color coding for each assessment method and another one preferred a color coding from green to yellow to red. We deliberately avoided a color coding that highlights anything else than problematic situations. Other subjects complimented on this fact.

Readability: One subject wanted larger buttons and larger letters. No other (negative) remarks were done concerning readability.

Form of Representation: The concept of the information levels and its meanings was not obvious to all of the test persons. For instance, the timeline was not identified as well as the assessment level. Captions for each section, may solve this problem.

6.2.2 Pictogram Level

The first section that should give an overview contains pictograms, that allow for a quick assessment of a problem and its neighboring problems. Several test persons used this section for a detailed analysis of the problems. The pictograms were perceived as realistic situations. This perception was supported by the fact that the men shown at the pictograms were similar to the digital human being shown by the film. Thus, there was no difference in the level of detail

perceived. Most parts of the pictogram were comprehensible to the users and they liked that the neighboring problems are shown. The test persons expected the chosen problem to be the one in the middle of the screen. A revision of the interactive visualization should consider this. As well as the expectation that problems that are shown in a line are perceived as sequential problems in time. The controls (arrows for jumping back and forwards) of this section were intuitive, but the button for showing the next five problems was never used. Thus, it seems to be unnecessary.

6.2.3 Assessment Level

The second layer shows the values of the ergonomic assessment methods. Especially users without any experience in ergonomics were unable to see the connection between the pictograms and the assessment table. Following this connection should be more visible, a grey shadow is not sufficient. There was some confusion about the plain fields for the assessment methods EAWS and climate, they were interpreted as the absence of problems. The missing of data should be shown in a different way than the absence of a problem, for example as a light grey field. Is there a whole assessment method missed, this line should be erased from the table. Showing the assessment numbers color coded as well as alphanumeric seemed to be unnecessary for a first impression. Showing the exact number after selecting the problem may be sufficient. These numbers should be complemented by indicating its unit (e.g. decibel (dB) in the case of noise). In order to make this tool internationally available, it should be considered to use the units generally used in the chosen language.

6.2.4 Timeline

The third section shows every problem on a timeline. Two controllers are used for selecting a certain period in time. The subjects liked this solution and understood its functionality intuitively. Although, the test persons often used alternative ways of interaction for selecting a period of time. The relationship of the timeline and the video sequence was not clear to all test persons. Two subjects expected that the whole timeline is synchronized with the duration of the video and they tried to control the timeline with the cursor of the video player and vice versa. This situation uncovered the need of indicating the time spread of the video sequence on the timeline visually. Another problematic feature was the partition of the timeline. This partition is accurate to the second: If the controller is placed within a second, it automati-

cally jumps to the beginning of the second. This was confusing to the test persons, especially when they tried to select the beginning of a problem, but did not meet it exactly. Thus the controller jumped back to a point before the problem. It would be conceivable to allow only the positioning of the controller on exact seconds or a second-wise visual scale may put things right.

6.2.5 Detail Level

The last section should allow for a detailed analysis of the selected problem. It consists of the video player and a detail view. The detail view was not part of this evaluation. Concerning the video, one test person used it not only for a detail analysis but also for gaining a situation overview. Their first step was watching the video. Nonetheless most of the subjects used the video for detail analysis and they liked that the video sequence showed directly the selected problem. As noted above the test persons expected a synchronization between the video and the timeline. Hence, a parallel run through the problems on the timeline, should be done while playing the video sequence. Furthermore a participant suggested to mark the problem directly in the video. Sometimes the controls of the video player were confusing. One subject has problems in leaving the full screen mode and proposed a backwards button. Furthermore the leaving of the loop (showing the selected problem) back to the whole video sequence seemed to be difficult (the users had to stop the video loop and then to restart it). A possible solution may be the use of two play buttons. One starting the selected sequence and another one starting the whole video. The advantages and disadvantages, should be investigated in another test, in order to avoid too much complexity of the interface.

6.2.6 Tooltips

At some elements of the visualization tooltips were used in order to give some detailed information. For example when hovering over a problem on the timeline, a pop-up shows the exact time span of the problem. This feature was widely used by the subjects. They used it for identifying the starting point of a problem or for finding out the exact weight or the exact body angle at the hints next to the pictograms. However, the majority of test persons discovered this functionality rather by accident. Therefore, the information shown by the tooltips should also be accessible on an alternative way (e.g. showing the weights and body angles next to the pictograms permanently).

6.2.7 Complementary Elements

Sometimes the test persons wished for some elements or functionality, that was not considered yet. One subject wanted to select a time span on the timeline directly by typing its starting and ending point. Another test person also wanted to show the video sequence correlated to the whole time span chosen on the timeline. Furthermore, the subjects looked for a possibility to filter problems. For example they were interested to see all problems with a bad body posture. A zoom function for a more detailed analysis in the video was suggested. Further wishes, like information about the composition of the assessments, are already planned to be shown in the detail level.

6.2.8 Evaluation of the Questionnaire

The arithmetic mean of all question categories is a 2.4 (good), this means that in terms of software ergonomics there is not much need of action. Only the category “individualization” was badly graded by the test persons (3.5). During the development process we focused on the main requirements as stated in Section 2. For a final product the following aspects should be considered (VBG, 2016):

- Can the user choose the way of interaction? (Mouse, keyboard, command prompts, touch)
- Is the software adjustable in terms of assistance (help, hints, list of abbreviations, ...) and display qualities (color, text size, ...)?
- Is the software adaptable to the users characteristics (language, skills, cultural background,...)?

Some of these points were already criticized by the test persons during their walk through. For example considered one subject the texts and buttons as too small. The font size as well as the size of the controls should be adaptable. Further improvements may be achieved through additional help options. Some have already been discussed in section 6.2.1 (e.g. tooltips that the user can switch on and off). Likewise, we already discussed the implementation of language specific features in section 6.2.3. Merely the control by mouse was not criticized yet.

Additional to these questions the group of experts was asked about the relevance and efficiency of the prototype in practice. The relevance of the prototype was considered as “good” by the experts. The visualization is a simple and well arranged interface, that allows for an analysis of the working processes and for a detailed ergonomic assessment. The efficiency was seen as moderate. The reasons for this laid in the font size, the controls on the timeline, the complexity of the visualization, the lack of descriptions about

the numbers. Nevertheless the test persons labeled the tool as usable.

7 CONCLUSION

The facts and figures from business and research showed that there is a general need for an adequate visualization of ergonomic data. In a previous paper (Heft et al., 2015) we discussed the user requirements and introduced a new design approach. In this work, we presented the final design including an evaluation of the implemented prototype. The visualization take the following user's wishes into account. First and foremost, the participants expressed the desire for an easy-to-use application. The second wish was a user-friendly presentation of the analysis data. The most important ergonomic problems should be displayed at a glance and additional information are easily accessible when required.

The final prototype was validated in a user study. A qualitative study with seven persons, including three ergonomists, was carried out. The test resulted in the overall score "good". Therefore, from the software ergonomic point of view, it is not compulsively necessary to improve the program. Nevertheless, some features have been worked out which could enrich the program (in a subsequent version). All participants, especially those of the non-experts, were able to solve the tasks independently and quickly. Thus the goal of an interactive and intuitive overall presentation of ergonomically critical situations (over any period of time) was achieved.

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