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Visualising Web Accessibility Performance to Raise Awareness and Understanding Amongst Product Stakeholders

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Abstract

With the rapid development and increased use of technology, making technology accessible for every user is becoming even more important. A vital part in the process of achieving this is evaluating products as part of the development process. This design-oriented study explores how a visualisation of a product's accessibility performance can aid in creating a more inclusive and accessible product by increasing awareness and understanding amongst product stakeholders. To explore the requirements of such a visualisation a prototype was developed for a music streaming service's desktop application and evaluated through a study with six stakeholders.

All participants had a positive attitude towards the prototype and expressed that it helped them find accessibility issues. Five out of six participants felt they understood what an issue entailed and whom it could affect. Several different areas of usage were proposed by the participants, who also believed a broad group of different stakeholders could benefit from using a tool like this. The results showed that the proposed design could increase awareness and create a deeper understanding for accessibility issues amongst stakeholders. No specific part of the design could be identified as more valuable than the other, which indicated that the value lied within the prototype as a whole. Together all parts created a versatile tool that could be used to fulfil different users' need in different situations.

Sammanfattning

Den snabba utvecklingen och det ökande användandet av teknik ökar vikten av att göra teknik tillgänglig för alla användare. En vital del I denna process är att integrera utvärdering av produkter i utvecklingsprocessen. Denna designorienterade studie utforskar hur en visualisering av en produkts prestation med avseende på tillgänglighet kan underlätta skapandet av mer inkluderande och tillgängliga produkter, genom att öka medvetenhet och förståelse hos intressenter i produktutvecklingen. För att utforska kraven på en sådan visualisering utvecklades en prototyp för ett musikstreamingföretags skrivbordsapplikation och utvärderades genom en studie med sex deltagare.

Alla deltagare visade en positiv attityd mot prototypen och uttryckte att den hjälpte dem hitta problem med tillgänglighet. Fem av sex deltagare kände att de förstod vad ett problem innebar och vem det kunde påverka. Flera olika användningsområden föreslogs av deltagarna, som också menade att en bred grupp användare kunde gynnas av att använda ett verktyg som detta. Studiens resultat visade att den föreslagna designen kunde öka medvetenhet och skapa en djupare förståelse för tillgänglighetsproblem hos intressenter i produktutvecklingen. Ingen specifik del av designen kunde identifieras som mer värdefull än någon annan, vilket indikerade att prototypens värde ligger i dess helhet. Tillsammans skapade alla delar ett mångsidigt verktyg som kan fylla olika användares behov i olika typer av situationer.

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ABSTRACT

With the rapid development and increased use of technology, making technology accessible for every user is becoming even more important. A vital part in the process of achieving this is evaluating products as part of the development process. This design-oriented study explores how a visualisation of a product's accessibility performance can aid in creating a more inclusive and accessible product by increasing awareness and understanding amongst product stakeholders. To explore the requirements of such a visualisation a prototype was developed for a music streaming service's desktop application and evaluated through a study with six stakeholders.

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AUTHORS KEYWORDS

HCI; Accessibility; Web Accessibility; Web Accessibility Evaluation; Visualisation;

INTRODUCTION

As the technology changes and the range and capabilities of devices continue to increase, technology companies and businesses need to better understand Human-Computer Interaction and what it means for providing great user experiences. User experience can include many different aspects such as the user interface, navigation, context of use and accessibility. This study will focus on one specific area of user experience, accessibility, and explore how visualisations could be used to increase the awareness and understanding of accessibility.

Web accessibility has several different definitions within the scientific, research and design communities. From a large survey [19] performed with people interested in accessibility the following definition by the Web Accessibility Initiative (WAI) [11] was ranked as most preferred. "*Web accessibility means that people with disabilities can use the Web. More specifically, Web accessibility means that people with disabilities can perceive, understand, navigate and interact with the Web, and that they can contribute to the Web"*. One frequently applied method for evaluation of web accessibility performance is the usage of automatic evaluation tools that assesses a website's conformance towards a set of web accessibility guidelines [3], called conformance checking [1]. For instance, checking if alternative texts are available for all images.

Based on the data provided from conformance checking, a prototype with visualisations of this data was developed and studied to evaluate the following research question:

How should a visualisation of an application's accessibility performance be designed to raise awareness and create understanding amongst product stakeholders?

The prototype was created for a music streaming service's desktop application, as an internal tool that visualises its accessibility performance. The aspiration was that the visualisations in the prototype would facilitate in raising awareness and understanding of existing accessibility problems by making the information easier to take in. Awareness is in this study defined as the state of being conscious about something, having knowledge of a situation. Apart from facilitating comprehension of data the visualisations could also open up to a broader target group with different professions, in addition to developers who are used to the output format of current conformance testing tools.

Delimitations

This study will focus on evaluating accessibility solely for web content, limited to issues detectable by automated web accessibility evaluation tools performing conformance checking, described in the background section.

BACKGROUND

The rapid and steady evolvement of web development standards and techniques, along with the increased usage of dynamic content, creates a complicated challenge for delivering accessible web content even though many web accessibility standards and evaluation methods exists [3].

Evaluating Accessibility

Web accessibility evaluation is the procedure of assessing how well people with disabilities can use the web, which includes evaluating web content, authoring tools, user agents, assistive technologies and underlying web technologies [10]. Henceforth the term web accessibility evaluation will be used for evaluation in regards to content only, due to the limitations of this study.

Evaluation of web accessibility is often performed using a combination of the following methods [3]: using web accessibility evaluation tools, expert evaluation, user testing and surveys for web administrators and developers. When using the first three methods, the aim is to test accessibility and find issues while when using the last one, surveys to web administrators and developers, the aim is to discover why there are issues [3].

Automated Web Accessibility Evaluation Tools

Conformance checking has the ability to detect a wide range of problems (included in the chosen set of guidelines) for a diverse group of users with different impairments [5], even though it is limited to the coverage of the guidelines they check towards (as discussed in the section about accessibility guidelines). Checking conformance manually takes a lot of time and effort, which can be reduced by using a software tool or online service to do this instead [15]. Using automated web accessibility evaluation tools has been concluded to be relatively cost-efficient [5]. Furthermore, it has the benefits of scalability and objectivity [13], and is necessary for providing real-time updates [18].

Automated evaluation tools have some limitations worth keeping in mind. Certain guideline checkpoints cannot be fully verified by machine, e.g. assessing the content of an alternative text for an image. Which makes an automated conformance check less detailed than an expert analysis [13]. Another drawback is that they are not reliable in differentiating important and unimportant issues [5], they provide an indication of whether a checkpoint has been violated but no insight on how severe the impact is for the user [18].

Vigo et al. [18] found that solely using automated tests has negative effects on a product's accessibility performance since there exists a large number of guideline checkpoints that cannot be evaluated by an automated tool. Additionally, there are risks that the tool mark something as an issue by mistake or miss finding some of the existing checkpoint violations. Therefore Vigo et al. recommend involving human judgement as a part of the evaluation process. Given that there are certain subjective checkpoints, an expert analysis is always required [16]. Furthermore, the results from the study performed by Vigo et al. [18] showed that for more inaccessible pages the automated testing tools had a higher level of correctness and gave more similar results than for the more accessible pages with a small number of issues.

Given its limitations, the purpose of an automated web accessibility tool can be viewed to be to *"present the potential accessibility issues in a way that a human evaluator, expert or novice, can understand what is being evaluated, the importance of specific checkpoints for overall accessibility and what groups of users will be affected if an identified accessibility problem can't be easily solved."* [16].

Visualising Accessibility

When determining conformance towards a set of guidelines with web accessibility tools some tools present the results in text only, as lists of problems with connections to the source code [2, 17]. Presenting problems along with the source code might be preferred by people familiar with it, like expert evaluators, designers or developers evaluating their own product [16]. However, a user study performed by Tanaka and Da Rocha [16] indicated that inexperienced accessibility evaluators prefer a visual presentation on the evaluated website of the guideline checkpoint violations, since this facilitates to identify which areas are affected by the different specific checkpoints. They also found that a desirable feature for this user group was the possibility to customize the reports, enabling sorting by properties like number of occurrences.

Visualising data enables people to gain insights and knowledge in a way raw data does not support. By observing charts and diagrams people can mentally interpret and draw conclusions about the visualised data. With the help of how the data is represented visually, people are able to interpret and draw conclusions from it [9]. An example of visualisations being used in web accessibility evaluations is Bailey and Burd's [4] use of a tree-map visualisation to represent the accessibility of a website, that could be used for management. To gather data they used conformance checking with an automated tool. The results of their study showed that problems and changes were quick and easy to observe. Furthermore, for presentations and reports to non-technical persons visualisations are optimal. Their visualisation provides management with the ability to follow the evolution of a website. This could be used to track performance and provide insights on what parts and which teams that lack in accessibility performance and help provide fixes such as relocating resources and reviewing processes, tools and techniques.

Accessibility Guidelines

Several different accessibility guidelines have been developed, each consists of a set of recommendations on

how to make web content more accessible. The Web Content Accessibility Guidelines (WCAG) 2.0 [7], the most recent version developed by WAI, is widely adopted. However, the limitations to validity and testability of accessibility guidelines are well recognised [5, 6]. Research has shown that guidelines only cover around 50% of the issues users encounter, which highlights that sole reliance on guidelines is not enough to ensure accessible content.

Disabilities Addressed in WCAG 2.0

Following guidelines often ensure high usability to all users, disabled or not, although they are created to address issues encountered by people with disabilities. For WCAG 2.0 disabilities addressed includes blindness and low vision, deafness and hearing loss, learning disabilities, cognitive limitations, limited movement, speech disabilities, photosensitivity and combinations of these. Table 1 shows the percentage of guidelines in WCAG 2.0 connected to the following disability groups [12]: communication received and producing, cognitive, hearing, visual and upper limb impairments [8].

Group of Impairment	Percentage
Communication received and producing	47,54 %
Cognitive	39,34 %
Hearing	13,11 %
Visual	63,93 %
Upper limb	13,11 %

Table 1. Distribution of WCAG 2.0 guideline checkpoints relating to different groups of impairments.

This paper aims to further explore web accessibility evaluation, by exploring a way to visualise the results of automated web accessibility evaluation tools. The visualisations are used to study how a visual tool could facilitate in creating a more accessible application by increasing understanding and awareness of accessibility amongst stakeholders involved in the development of a product.

METHOD

To explore the stated research question a prototype visualising accessibility performance was developed and evaluated through a study. The study included six participants: three product designers (P2, P3, P4), one frontend web developer (P5), one director of engineering (P6) and one software tester (P1) working with quality assurance. All were employees at the company for which the prototype was developed. The participants were aged between 23-41 years and had between 4-20 years of experience working within their profession.

Study

The study consisted of two parts: interaction with the prototype followed by a semi-structured interview. The sessions were held in a user research lab with the participant and the researcher present. All sessions were captured with video and screen recording, which was transcribed and analysed. The results were analysed by grouping the collected data into four different areas: task performance, key questions (mentioned in the "Interview" section), potential users & usage and design feedback. For the last area the data was further divided into different groups based on which view in the prototype it concerned.

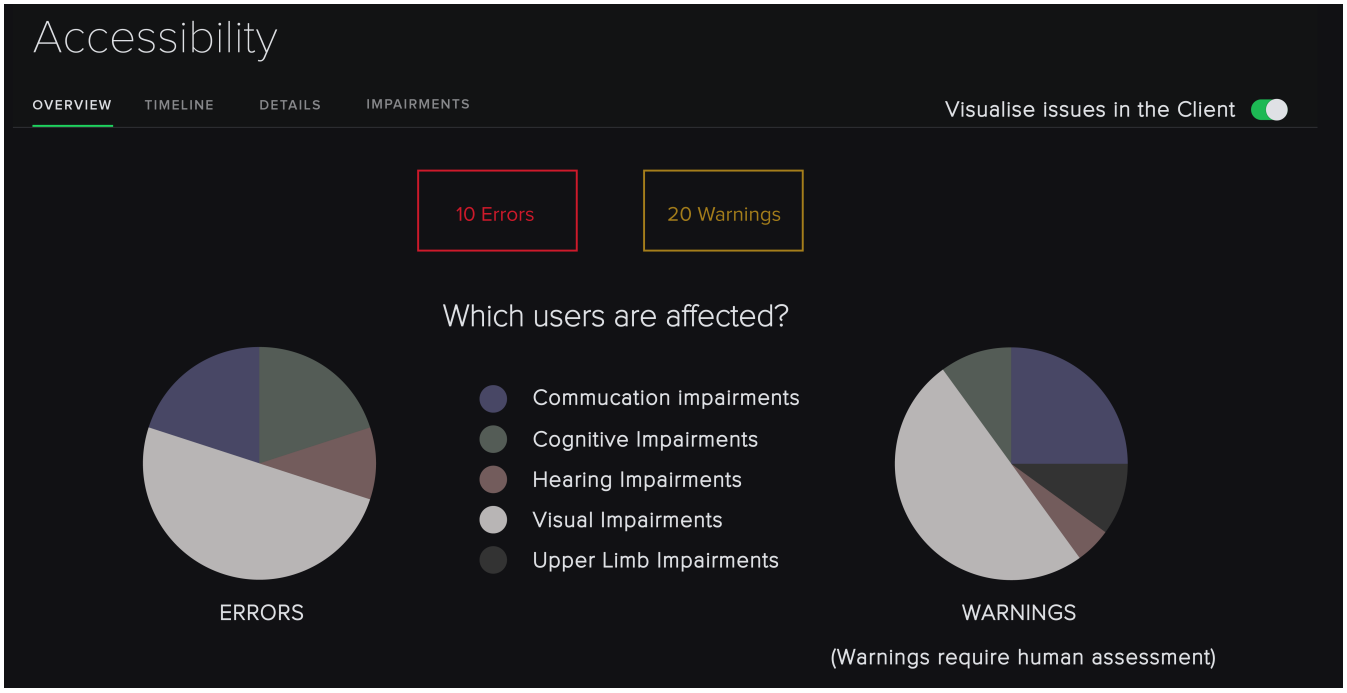

Figure 1. The overview presenting existing numbers of errors (in red) and warnings (in orange) along with two pie charts displaying their distribution over different groups of impairments. The groups of impairments are listed in the legend in the middle.

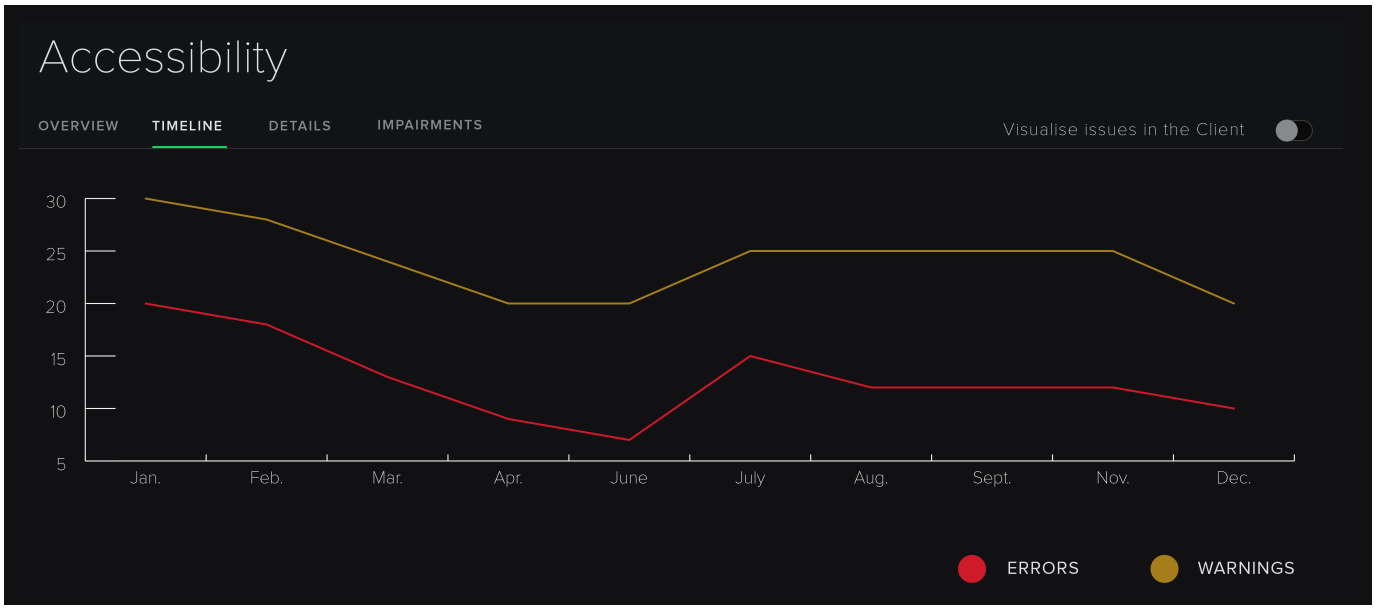

Figure 2. The timeline view displaying the occurrences of errors and warnings over time.

Due to a technical error the recording for the later half of the session with P2 is missing sound, which led to some loss of data.

Interacting with the Prototype

The first part of the session was designed to get an understanding of how potential users would interact and use the prototype and furthermore explore if the data presented was easy to find and comprehend. The participants were asked to answer seven questions using the prototype while thinking-aloud. The questions were designed to make the users explore all features of the prototype.

Interview

Interviews were held to understand the participants' personal experiences and thoughts regarding the prototype. Four key questions were identified:

- Did the prototype help you find accessibility problems?
- Did you understand what a given accessibility problem entailed and who it could affect?
- Could the prototype help you prioritise which problems to focus on?
- Does the prototype feel reliable?

Questions one and two are directly related to what the prototype is designed to do, and evaluates its core functionality: finding and understanding issues. Question three relates to the desired ability of facilitating when prioritising tasks. The last question asks if the prototype feels reliable and if the participants feel that it can be trusted to find potential problems. An important aspect required for adoption.

Prototype

The prototype was designed to visualise accessibility performance for a music streaming service's desktop client. The visualisations were created to represent data generated from automated web accessibility evaluation tools. However, for this study the generated data was simulated. For the initial parts of the design process a senior product designer was involved, after which the prototype was developed through parallel prototyping. The final design was created with Adobe Illustrator and made interactive using the tool Invision.

The prototype includes four main views: the overview (Figure 1), the timeline view (Figure 2), the details view (Figure 3) and the impairments view. Additionally, the prototype includes a feature that visualises existing errors in the client by highlighting part of the layout where issues exist with a red marking. This feature is accessible from all views and was designed to support users inexperienced with accessibility evaluation, in line with the findings of Tanaka and Da Rocha [16]. Additionally it provides more context to users that have little or no experience with code.

In the overview the user is presented with the present number of errors and warnings, violating the WCAG 2.0 guidelines. Additionally the view contains two pie charts, one for errors and one for warnings, displaying the distribution of existing issues over the five different groups of impairments presented in the background section. An explanation of what impairments and diseases these groups includes is available in the impairments view, intended to provide more context and information to users with little or no knowledge of accessibility. As implied by the name the purpose of the overview is to provide a view of the current situation and show how different user groups are affected.

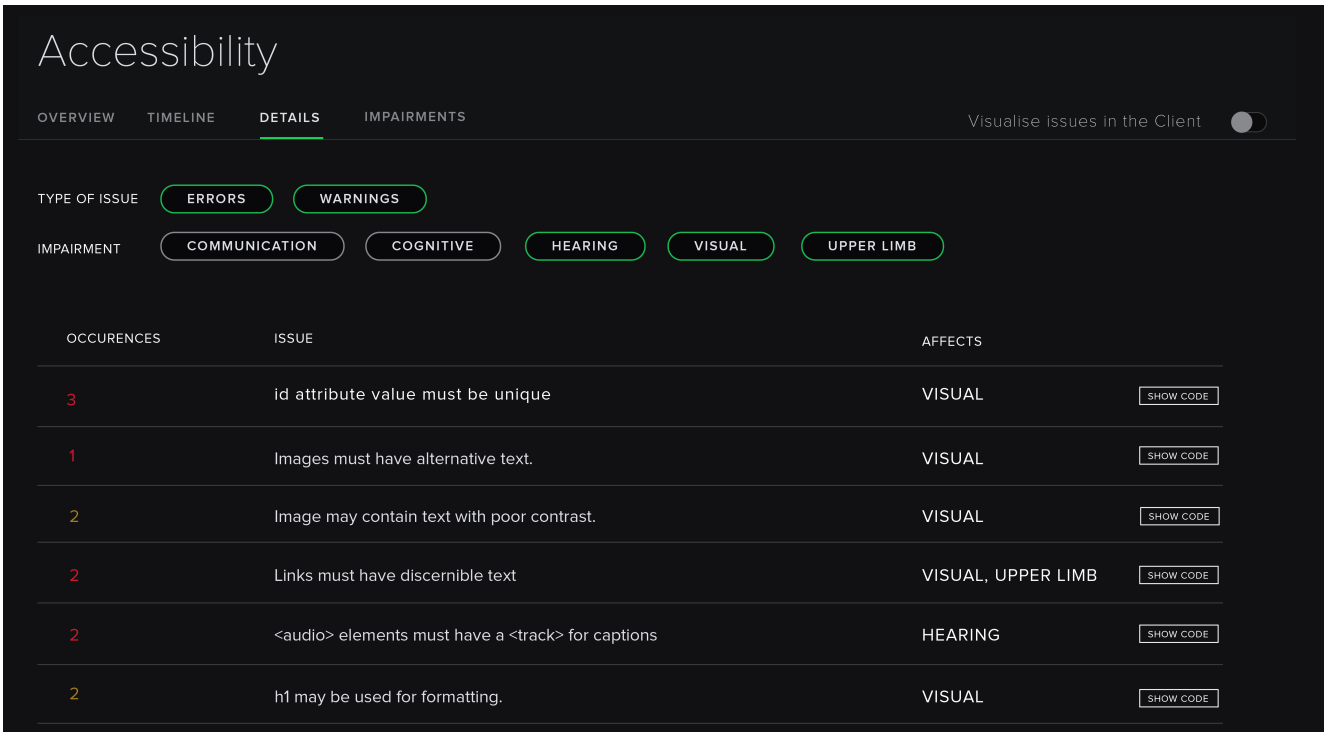

Figure 3. The details view showing a list of all issues with filtering options above. The following attributes are listed for each issue: occurrences, description and impairment group(s) affected. Red colour indicates an error, orange a warning. On the far right side of each row is a button that shows the violating part of the code in a modal window.

For an overview of performance over time the prototype contains a timeline view, which displays the number of occurrences of errors and warnings over time. This feature was added to provide a way to track the company's accessibility performance, identifying positive or negative trends. This could be used as a tool for managers in similarity to the tree-map visualisation created by Bailey and Burd [4] that made it easy to spot changes and get insights on how different parts of the product was performing.

Showing the issues behind the numbers, the details view was designed to let users view all existing errors and warnings. The view displays a list of all issues. Multiple occurrences of one guideline violation are grouped together in one list element. For each issue (each list row) the following attributes are included: occurrences, description of violated checkpoint and the impairment group(s) affected. Red colour on the number of occurrences indicates an error, orange a warning. Included for each issue is also a button that displays the violating part of the code in a modal window. Filters are provided to facilitate in finding specific issues and to support some form of customisation as Tanaka and Da Rocha's [16] study found important.

RESULTS

All participants expressed a positive attitude towards the prototype and said that it could help them find accessibility issues, which was one of the key questions mentioned in the method section. P1 said that the prototype could *"help you rethink about how we design or develop or implement components and parts of the application"* and P3 expressed that *"This could change the culture of the company […] to shift slightly more to thinking about this [accessibility]"*. Furthermore, P3 showed excitement over the prototype saying that *"I think this is really great. I think this is really exciting. I haven't seen anything like this [at the company] the whole time I've been here, 3 years in April"*.

Concerning the second key question, regarding if the participants felt they understood what a given accessibility problem entailed and which users it could affect, five of the participants (P1 and P3-P6) answered yes to this. P2, the one participant who said no, explained the reason might have been a lack of commitment to the task: *"I guess I just scanned it, maybe I didn't care enough [...] I didn't kind of have a new empathy for these problems […] maybe I was a bit dismissive about that"*.

Performing the Tasks

Five of the participants (P1, P2, P3, P4 and P6) managed to complete all tasks required to answer all questions. P5 needed further explanation to answer two of the questions but were quick in completing all other tasks. For the majority of tasks all participants navigated to the right view straight away. When asked to find what the group cognitive impairments included P3 made a detour to the details view before navigating to the impairments view, where the answer was located. P1 and P2 also visited the details view, then tried to find the answer by interacting with the

overview page before finding the way to the impairments tab. When trying to find the number of occurrences of a certain warning P3 tried to find the answer by interacting with the pie chart for warnings, in the overview, before locating the answer in the details view. P6 started by navigating to the details view but made a detour to the overview before heading back to details to find the answer.

None of the participants expressed that they considered any question hard to answer, P4 thought the opposite and said it to be very easy. According to P1, using the prototype for about one minute before answering the questions would have made it easier. P2 said it was easy to answer the questions when in the right view and seeing the information. The hard part was finding which section to go to since the names of the views didn't match the names P2 had in mind. For P5 the tricky part was transforming what the researcher asked for into what to find.

Features and Layout

Regarding the design of the prototype, P3 expressed that the layout of the prototype felt very intuitive, overall it felt clear and quite easy to navigate around and continued with saying that *"Some of the foundational elements of being able to communicate accessibility issues has fallen into place, so that's quite nice to see"*. Furthermore, P6 commented that the layout was nice because it felt consistent and familiar since it resembled the one in the actual product, which P6 felt makes the use easier. However, P2 was initially confused by the similar layout, wondering where in the app this tool existed, but mentioned this probably was not a problem since the user would open the tool themselves when using it. P4 considered it really good that it was very intuitive to immerse yourself in the data.

Overview

When asked what the participants considered that the overview provided to them P1 answered that *"It doesn't contain so much information but I think it is enough to just get a better grasp and understanding of accessibility and what it means"*. P6 said that the overview provided very simple information at a glance. A high level summary, knowing there is more information there. According to P6 it was useful knowing the errors could be divided into five groups (one for each group of impairments). Together with the timeline the overview was the most valuable feature for P6. One participant (P4) expressed a wish for displaying exact numbers for the charts.

P2 explained that the overview would be useful to check each day or once a week to see how many issues existed, that it would be nice to see how many errors there were in the parts of the app they worked with. One way to use the overview, according to P3, is as a tool for internal communication *"it helps me to tell a story to stakeholders or a product owner that may be in another team, for example like we're slipping up in these areas and it's affecting these people. And I can't really tell that story I guess without something like this, without this kind of visualisation"*.

Timeline View

For P1 the timeline provided a way to see how the company attacks issues and how the trends go, if there is improvement or not. However, P1 didn't consider it as one of the most important metrics. According to P3 the timeline would be the view where product owners and team leads spent much time. P4 expressed that the timeline was a way to see if the company is improving or making things worse as they release new versions to users and added that it provides a way to track if proper quality assurance reviews are performed during releases. If the timeline goes up P4 said that maybe the teams are not sufficiently concerned about accessibility when creating the product. Like with the overview P4 requested the ability to show exact numbers for the line graphs, even if you could retrieve values by mapping them to the axis.

Four of the participants (P1, P3, P5 and P6) had suggestions for expanding the timeline view. Viewing more than errors and warnings was asked for by P5, who meant that this would add a possibility to see in which ways the company is improving or getting worse. Like P5, P3 wished for more information to be added to the timeline and proposed that by contextualising the timeline it could offer a way to weave a nice story behind it *"So you could say in June more people had free time because others went on holiday for example. So a few developers were able to just crank on a bunch of accessibility tasks for example and that would explain why the errors dropped in the middle of June*". The participant also provided an example story of why the occurrences of issues could increase *"it could be these spikes could happen when we bring in a new feature and the people within that team they weren't very clued up on accessibility, so they just deployed a bunch of things [...] and they weren't really assessed, hence the peak in errors"*. From this example P3 suggested that the company, from this kind of view, could understand the need to become better at educating teams in general and become more aware of accessibility. Since the timeline can retain information over time it can be used to refer back to things, perhaps find patterns and trends according to P3, ending with "*So this has the potential to tell a lot"*.

Apart from adding more information, the ability to interact with the timeline was requested. P6 had an idea to add a filter to the timeline and have thumbnails appearing when moving over the timeline, showing elements with errors. Enable zooming and adding a slider was suggested by P3, along with the ability to toggle between teams. P3 expressed that the toggling would enable more learning *"I mean if there are three teams for example you could toggle through and I could see that one team has really low errors and hardly any warnings then clearly they are doing something right and I can approach that team and ask them*

hey guys I noticed your timeline is really great. How have you done that? What are you doing?".

Details View

Participants P3 and P4 mentioned that the details view is where they could find specific things. Both P1 and P3 expressed that the view would be beneficial for developers. Something the participating developer, P5, confirmed with saying that because of being a developer the details view was the most valuable feature of the prototype. P3 viewed it as the to-do tab where a developer would do their work, sorting and filtering to zoom in to the tasks that need to be done and using the "show code"-button for accessing the code. Both P3 and P6 it was helpful that the tool brought the violating code to its users, relieving developers from the effort of having to scroll through lots of lines of code to find the problem. P6 expressed a wish to add a hint for the solution to an error, e.g. a short code snippet. P1 saw that the details view created an added value to the prototype *"The most tools I use would probably only contain the visualiser that points out all the problems. Here where you can actually see the list it provides much more context to the tool. It is nice"*.

For teams working on fixing existing errors and understanding them P4 considered it to be crucial to be able to go into more detail and dig deeper. P3 expressed the importance of the details view and being able to get to the end of the problem, to find the bug and fix it. *"I guess though in all honesty if you took out the details tab then you don't even know where to begin in terms of grabbing the problem and fixing it. So taking this away would break everything in my mind"*.

Impairments View

P4 explained that the impairments view is *"explaining which types of diseases fall into which category […] It gives me the ability to understand what they mean […] this I think is a good way to clarify this for everyone"*. P5 said that *"It gives you an overview of what kinds of impairments there are. A lot of people probably don't know that, I like that page because of that"*. P2 expressed that it was good to get an explanation of the impairment groups and said that some of the things listed were things they would never have considered which P1 also commented on *"the impairment [view] was really good where you could actually see what it [the groupings] means. Maybe you don't think about Asperger's syndrome as a communication impairment. Maybe you only think about people who can't speak. So this is great"*. P3 felt that the impairments view was very important *"if you took the impairments page away and then someone came to this and used it and they were new to accessibility, they are never going to really get the contextual background. The different demography of users that have impairments, so I think that is invaluable in that sense"*.

Three participants (P1, P4 and P5) mentioned that adding more information to the view could be useful. For instance, P4 and P5 both suggested adding links to a place where there is more to read and P4 commented, *"I want to read a lot on a ton of these things"*. Moreover, P4 proposed adding tools that could visualize the problems from the user's perspective *"when it comes to colour blindness there's tools that can help you look at the UI and see it more like they would"* and ended by saying that *"just having visibility to some of these issues I think that would be the crucial part and then of course the more information you have related to anyone of these points it's just going to help you make more educated decisions"*. P1 said that explaining for example what visual impairments actually means and how many visually impaired users the company has makes it easier to understand why they should prioritise accessibility. Moreover, P1 and P3 proposed that video could be added of users with different impairments interacting with the product. P3 saw this as a way to humanise the issues. With regards to this P2 expressed that *"maybe it would be cool to get a feeling for these problems more as well. Like what does it look like for those people when they have those problems, I can't even imagine because I don't have any of these disabilities"*.

Visualising Issues in the Client

P1 was positive towards the existing feature that visualises accessibility issues inside the actual product, the client, *"It highlights in real-time what the problems are. This is extremely good for like say testing"*. P1 continued with saying that testing accessibility is hard when having to install for example a screen reader software for desktop, enable it and then test by going through all the views. The participant thought that this feature would make this easier *"This [visualising in the client] basically you could turn on and just test other stuff you see in the meantime. It just makes stuff so much easier and it would also make it easier for like product owners (PO) or engineers to just enable it and see what's happening. Because it is really hard, which is bad, for a PO to just turn on a screen reader and use the client, that would never happen. This makes it much easier"*. When asked if the prototype provided an understanding of how the company is performing in terms of accessibility P1 answered that this probably could be provided by using the visualising tool in the live client and navigating around. Furthermore P1 answered that this feature was the one considered to be the most valuable.

According to P2, a potential usage for this feature would be to check the sections the user is working with. When hovering over an error a tooltip appeared with details on what the issue is and whom it is affecting. P3 felt that the description of whom the issue is affecting humanised the problem a bit more, making it more relevant, so developers can understand the reasons behind it *"It is one thing to have a job and just do the tasks but to understand the why is really important as well and that is what that is kind of answering"*. P4 also commented on the information in the tooltip explaining that this gave clarity to what the issue was, providing very useful information on how the element

and impairments can relate to each other. P4 added that even though more experienced users might not need this *"there is always going to be a need for someone to dig a bit deeper into what the problem is because they won't have the understanding*" and said that *"having these descriptions I think is a way for us to better understand the problem itself and then be able to make better decisions when we start prioritising"*.

P3 expressed that a tool only relying on showing code snippets is not the best because it might not be for everyone. For designers the visualisation could be a way to engage with the problem in a way that is more familiar to them. P3 explained the different needs of developers and designers and considered this feature to have the benefit of giving the issues more contexts, making them more apparent *"Maybe as a developer you are used to seeing code and in your mental model you know that's the client and you know where to go. I think for someone who is more a visually thinker or a designer this would definitely be more useful because it is contextualising things. Also you can see relationships perhaps a lot better. Maybe that's an easier way to catch things by scrolling through the views in this way [...] So I feel like this has an added benefit, it is not the same as the detail page. It does give the context a lot clearer I think and makes the problem more apparent"*. One of the participating designers, P2 expressed, like P3, that the visualising tool would be appealing for designers by saying *"I feel like if I turn on that switch [enabling the visualization] I would notice it [the issues] more whereas just reading through the list might not impact me so much. But if I saw my section had an error then that seems like it would have a stronger impact on me"*. Another designer, P4, said that this feature was especially helpful when finding accessibility issues since it not only told what the issues were but also made the participant see where they were.

Possible Improvements

Apart from the suggestions previously mentioned P3 had two non-view specific suggestions of possible things that could be added to or changed with the prototype. P3's opinion was that the prototype was very data-led and proposed bringing in more human aspects to it to contextualize the problem more and increase engagement. To achieve this P3 advised to review the use of language, imagery and videos.

P3 also considered the tool to be very concrete and expressed that it would be nice to make it a place for potential discussion by bringing in things such as a news and Twitter feed. That could build a community feeling around it, potentially making it stand the test of time better. P3 also said there could be room to bring in and link to different tools that could facilitate in creating a more accessible product, for example a colour analyser.

Potential Usage of the Prototype

Potential Users and Context of Use

P1 expressed that everyone working within product development could use the prototype *"I think it could be used by everyone, and should be used by everyone"*. Continuing with saying *"I think it is removing the threshold and just makes it so easy for people to use it in real-time, it is a really cool idea. Maybe it is easier than when it is in like a documentation somewhere hidden in the intranet or you know in an email somewhere"*. Like P1, P6 thought everyone could use the prototype *"I would like to use this personally for all members of each squad"*. To have lectures on accessibility, to give it exposure and make people understand how to use this tool was something P6 suggested, to make sure people are aware that the quality of the work they are responsible for includes thinking about accessibility. P6 mentions the importance of speed at the company and said that *"And it shouldn't be fast or high quality. It should be like it's high quality and we can still do it fast. And tooling enables that, tooling and good feedback"*. P6 also saw a potential to use this in day-to-day activities making the tool a part of the daily routine of going through bugs and said *"I think it should be part of our like DNA, it's just something we have to do"*.

Both P3 and P5 suggested using screens at the office to display visualisations and data from the prototype. P2 thought designers sitting at their desks working could use the prototype. P2 also said that product owners probably would not use this since they already have too many tools. P3 believed both developers and designers could benefit from using this and suggested that managers could also use it *"I think for managers it's a nice way for them to tell a story how a team is performing, how the whole company is performing"*.

P4 could imagine wanting to use this type of tool every time a new component was going to be released, making sure it does not have any errors. Furthermore P4 thought it was very important to apply this checking as part of the quality assurance process, before things get shipped. P6 also commented on where in the process this could be used and suggested adding it in the build pipeline, preventing the code from building where errors exists. The developer would then be linked to the prototype for finding and fixing errors. P6 added that there could be a threshold value of a certain number of warnings that would be acceptable.

By having a dashboard like this prototype P3 expressed that the company could keep constant track on where they are improving and where they are slipping up, which P3 considered the most important thing and added that *"If we are committed to improving and doing that slowly over time we need something like this"*. P3 also saw another type of usage of the prototype, outside of the company, towards its users. If people dealing with these impairments could understand that the company have this kind of tool it uses, P3 anticipated that *"that is going to make them feel like*

they are a bit more appreciated and a bit more valued as a customer, especially if they are a paying customer, rather than just being ignored basically and being excluded from participation".

Prioritising

When asked if the participants thought the prototype could help them prioritise which issues to focus on all but P2 said yes. P2 expressed an uncertainty in how to go about prioritising and requested a way to see the severity of each issue, how big impact they had on the affected user groups, along with information about which user groups that are the most critical for the company. P3 and P5 both answered they would use the overview for prioritising. As an example P3 mentioned that from the overview they could see that the user group with visual impairments had a lot of errors, and that would make it a priority. Like mentioned earlier P4 thought the descriptions for elements with errors in the client could help in making better decisions when prioritising. P4 also added that identifying which impairment groups had the highest number of actual users would be an important aspect to consider when prioritising.

Company Performance Overview

The participants were asked if they felt the prototype provided an understanding of how the product was performing in regards to accessibility. Five of them (P1, P3, P4, P5 and P6) said yes. Due to the technical error no response was recorded from P2. P5 felt that the understanding was provided by the overview and P3 that it came from the timeline since it *"gives me the widest overview of how the company would be performing in terms of errors and warnings."*. P6 said this depended on several views. The overview since it provide statistics but also the timeline since *"what we really want to know is the state over time […] we need to know that every time we add a feature we're not making it worse"*.

Reliability

All six participants perceived the prototype as reliable. According to P2 this was due to the fact that the prototype was integrated into the company's product. Additionally P2 explained that the credibility was increased by the impression of a professional design.

P4 pointed out that because it was an internal tool at the company, it made it trustworthy "*I would assume that every time I look at a graph internally that it is giving me the information I need and it's all correct."* and added that if something in the graph was inaccurate or unsure they would expect that there would be a mentioning of it. Adding a timestamp that tells when the prototype was last updated would make it feel more reliable according to P3. P6 questioned how easy it was to collect the data accurately, if it was easy to detect all types of accessibility issues.

P1 mentioned that having a tool is helpful even though it might not be perfect *"I suppose making perfect tools is really hard because it could be custom ways of coding in some views […] I think the tool itself doesn't need to be pitch perfect as long as it shows some issues I think it would help a lot"*.

DISCUSSION

The result from the study shows that the designed prototype could aid the participants in finding accessibility issues. It also showed that it could help them in understanding which end users were affected by an issue and what that issue entailed. Furthermore, the prototype could be helpful when prioritising, which was expressed by four participants. All this points to the fact that this type of tool could be useful for working with accessibility and indicates that the chosen way of visualising the data managed to, at least to some degree, fulfil the general purpose of visualisations by enabling people to gain insights and knowledge [9].

The stated research question asks how a visualisation of an application's accessibility performance should be designed to raise awareness and understanding, of accessibility, amongst product stakeholders. To raise awareness, more people need to become conscious about accessibility, learning that it is an important part of user experience. The results pointed to the fact that the prototype could be used by a broad group of users, with both P1 and P6 saying that everyone, working with the product, could use it. This is promising in terms of raising awareness, since it means that the prototype could reach out to a large group of people. One participant (P3) expressed that the prototype could aid in telling a story when communicating internally around accessibility issues, creating opportunities to reach out inside the organisation and make other employees more aware. As a result it could help change the culture at the company, shifting it gradually towards thinking more about accessibility, as expressed by P3. This could create a more profound awareness of accessibility since it would make people more conscious about it in general and put it on the agenda in a more ubiquitous fashion.

When it comes to creating understanding amongst the product stakeholders, this would entail that insights gained from using the prototype made it easier to comprehend the situation and provided knowledge about accessibility. P1 clearly stated this was provided when saying that the information in the overview offered a better understanding of accessibility and what it means. The fact that four of the participants considered themselves to be able to understand the issues, what they meant and whom they affected, can also be viewed as a progress in creating understanding. Which is something P4 pointed out when saying that the descriptions of the issues were a way for people to get a better understanding for the problem itself.

The collected data from the results supports the argument that this tool could raise the awareness and understanding of accessibility amongst stakeholders. Potentially this could be related to improving the quality and performance, in terms of accessibility. Exploring a possible correlation

between these two however, lies outside the scope of this study.

Based on the positive attitudes toward the prototype, the high number of completed tasks during the study and the fact that all participants perceived the prototype as reliable, the results suggest that a tool of this form could have an impact. The participants had several ideas of potential usage of the tool and provided interesting feedback on its design and functionality. When interacting with it during the sessions, the participants gained new insights, which, if in a real situation, could potentially be applied to their work and affect different processes. This supports the case that a tool like this could be effective and take part in improving accessibility performance.

Interestingly, different participants found value in different elements and features of the design, depending on what role and potential situations of usage that they imagined. However, in total, all elements of the design were considered valuable to the participants in one way or another. This indicates that a benefit of the tool is its versatility.

One appreciated feature in the design was the tool for visualising issues in the client which, as P3 put it, could be used by more visual thinkers, like designers, as it contextualises the problem. This type of feature was also found valuable in the study performed by Tanaka and Da Rocha [16]. Another feature of the prototype, the timeline, has similarities to the tree-map visualisation created by Bailey and Burd [4] that also provided a way to track performance, enabling users to gain insights and draw conclusions from it. Adding more dimensions to the timeline, as suggested by four of the participants, could make it more powerful in terms of analysing the performance and reasons behind it.

No specific part of the design could be identified as more or less valuable than the others, indicating that the design as a whole is what creates the bigger value. The prototype depends on all parts of the design to create a versatile tool that can be used to fill different user's need in different situations.

Research Method

An interesting alternative approach to answer the stated research question could have been to perform a design workshop with a few product stakeholders. Design workshops offer an efficient way to gain creative input and valuable insights from the participants [14]. This could have resulted in a very different design than the one used for this study.

Another way to perform the study could have been to simulate different cases of usage, e.g. a meeting or quality assurance session, with one or several stakeholders, depending on the simulated case. This could have generated more accurate data around potential real situations of usage and the requirements around those.

Since the prototype used for this study did not display real data regarding the accessibility performance, no conclusion on how the prototype would actually work can be drawn. Populating the prototype with real information could potentially alter the appearance in such a way that the users ability to draw conclusions is negatively affected, for example by becoming overpopulated. Utilising real data for this study would therefore have been beneficial for the results.

Generalising around impairments is very hard. How different diseases, impairments and situations affects users varies and is very individual, which makes it very hard to categorise and divide people into specific groups. Since the prototype developed for this study uses a grouping of impairments it is important to make potential users of this type of tool aware of this and the fact that it cannot find all accessibility issues. Therefore is very important to promote that other evaluation methods need to be a part of the process to ensure a high level of accessibility.

Future Research

Even though some participants expressed an interest in learning more about accessibility, when wishing for more information in the impairments view, a potential challenge could lie in sparking interest and getting people committed to using the tool. Something that was not part of the scope for this study but could be investigated in future research. Furthermore, research on the usage of a prototype like this with real data, in real situations would probably lead to the finding of additional requirements on how to visualise accessibility performance. Lastly, as mentioned, this study did not explore whether or not increased awareness and understanding of a problem actually improves accessibility in the product as an effect of its use, a potential correlation that would be interesting to investigate.

CONCLUSION

This study looked at how to increase awareness and create understanding of accessibility through the design of visualisations presenting accessibility performance. The results showed that the proposed design could increase awareness of accessibility issues and aid in the process of understanding what an issue entailed and whom it could affect.

The prototype could be useful to a broad range of different stakeholders as the participants gave examples of potential users being developers, designers, managers, product owners and software testers. Furthermore, they suggested several different situations of usage such as meetings, quality assurance testing, prioritising, education as well as for tracking and analysing performance. Additionally, it could be used to tell a story when communicating around accessibility issues within an organisation.

The results from the study could not identify any specific part of the design as more valuable than the others. This indicates that the value lies within the prototype as a whole.

Together all parts create a tool that can be used to fill different user's need in different situations.

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