Modelling Age of End-users using Wire-frames

Hourieh Khalajzadeh[1][0000−0001−9958−0102], Tanjila Kanij[1][0000−0002−5293−1718], Aria YukFan Jim[2], Hyun Shim[2], Jue Wang[2], Lionel Richie Wijaya[2], Rongbin Xu[2], and John Grundy[1][0000−0003−4928−7076]

[1]HumaniSE Lab, Faculty of IT, Monash University, Australia
{hourieh.khalajzadeh, tanjila.kanij, john.grundy}@monash.edu
https://www.monash.edu/it/humanise-lab
[2]Faculty of Information Technology, Monash University, Melbourne, Australia

Abstract. The range of technology users is continuously increasing from adults to children as well as seniors. This introduces new age-related requirements and considerations. Modelling frameworks are used to assist the software development independently of the platform and the coding technology. However, very limited research has been done on age-related issues within the modelling and design frameworks. In this paper, we investigate how human-centric aspects regarding age can be better modelled by extending wire-frames. We collected both developers and end-users feedback through questionnaires and introduced an extension of wire-frames to cater for decisions regarding age within the modelling framework. We then conducted a usability testing by using the extended age-modelling wire-frame approach to design a news app. This shows that when using our extended wire-frames, developers can cater for different user types and their accessibility needs easily. We finally conducted cognitive walk-throughs with three personas, representing children, adults and seniors to evaluate the prototype app. The results proved the usability of the app for all age groups.

Keywords: Human aspects · Modelling · End-users age · Persona · Cognitive walk-through · Usability.

1 Introduction

There is an increase in the average age of the Internet users, with 73% of United States adults over the age of 64 accessing the internet [38]. Elderly users can face issues such as screen readability due to visual impairments, which is not usually an issue for the mostly young developers who design and develop most software [37]. On the other hand, the number of teenagers growing up with technologies is also increasing. The study by Hussain et al. [18] compares web-browsing behaviour between different age groups and discusses the issues teenagers have with poor visual designs, such as font size, background colour and layout of certain websites. These provide evidence for a need to better cater for different age groups of software systems end-users and carefully consider the limitations and abilities of these groups when designing a software [22].

Modelling Languages are used to assist the development of complex software systems with implementation concerns such as usability, security, persistence, and business rules independently of the platform and the coding technology [19]. Existing requirements modelling languages, including iStar 2.0 [12], and conventional modelling languages such as the Unified Modelling Language (UML), have been designed to model software functional and non-functional requirements. *Human-centric aspects* of end users of software, such as their age, satisfaction, preferences, working environment, and gender [23], are one of the most significant factors to the success of a software system. However, these have been largely ignored and not modelled properly during the system development process to date [15]. There have been works on modelling emotions and interactions of the users [33, 27, 34]. However, there is little or no provision to model diverse human-centric aspects of software end-users, including the age of the end-users.

In this paper, we present an extended wire-frame to improve the modelling process to better meet the human-centric issues regarding age. We critically analyse the existing models, present our own extended model, and eventually build a prototype, and evaluate it using personas and cognitive walk-through. Our research aim is to investigate how human-centric aspects regarding age can be expressed in current modelling frameworks. We initially investigate the type of modelling frameworks that are best fitted for adding human-centric aspects regarding age by collecting inputs from developers and relevant research papers. Next, we look into ways to best model user characteristics regarding age in software requirements and/or design models. Last, we discuss what application domains can benefit from human-centric aspects regarding age. Common applications include news apps, discussion forums, and social media. For the evaluation, we identify whether developers are easily able to create software systems with better usability for all age groups using our extended wire-frame. We also evaluate the prototype apps created using the extended wire-frame to understand whether the different user types are able to easily use the software systems. Finally, we apply cognitive walk-through with three personas, representing all three age groups, as a usability inspection method to evaluate the usability of our prototype app for users of different age groups.

This paper is an extended version of an earlier work that appeared at Evaluation of Novel Approaches to Software Engineering (ENASE) conference 2021 [20]. The key contributions of this paper include:

- Presenting an extended version of wire-frames to design the application specific to the age of the end-users
- Reviewing the literature on modelling the age of the users using personas
- Using personas to evaluate the usability of the method

The rest of this paper is organised as follows. Section 2 provides a summary of the research papers that are related to our study. We present our approach in Section 3 and our evaluation approach in Section 4. Section 5 presents our extended modelling framework including examples of the artefacts resulting from the research. We also discuss evaluation responses from our developer survey

questionnaires and the findings of our cognitive walk-throughs with personas. We will finally conclude the paper in Section 6.

2 Related Work

We reviewed a number of research papers related to extending modelling languages to support the modelling of different human-centric aspects, including modelling emotions, age, culture, language etc [10, 21, 40, 1]. We investigated how the languages were extended and which human-centric aspects were modified in these existing research papers. We also reviewed various works that extended existing modelling languages to capture additional non-functional characteristics [14, 13, 16]. We investigated what aspects could be changed in the existing modelling languages, in order to capture information about different age groups of end users. After our analysis, we developed a set of extensions to the widely used wire-frame based design notation [24] in order to model different end user ages, age-related implications on the design, and different design decisions based on user age characteristics.

2.1 Designing for different ages

We reviewed the key works done in three different categories related to designing for children, seniors and extending models to capturing emotions of end users. The age classification we used in this paper is called Life Cycle Groupings [41]. According to Statistics Canada, age groups can be defined as: Children aged from 0 to 14 years; youth aged from 15 to 24; adult aged from 25 to 64 years; and senior aged from 65 and above. The Australian Bureau of Statistics (ABS) uses a similar convention except they group both youth and adult as working-age population [2], which we named it as adult throughout the research.

Children: Mobile Educational Applications are used by Masood et al. [28] for usability testing. By recording with eye tracking glasses, they found some children had problems working with mobile applications. The system status is not apparent for them and they have a hard time finding out what to do next. They also had problems where they could not remember which page or button was accessed earlier. This children-oriented software needs to more clearly show the current state of the page, and sometimes the child users may need some guidance to do the next step. Help toolboxes and documentation were identified as necessary. Another important factor is to consider whether the buttons and menus are simple enough for children. Buttons and menu links should be easily identified as being clickable while items such as menu headings and titles should be easily identified as being not clickable.

A Fingerprint app [36] is used by Pan, to describe how to design the software user interface for the children. This work discusses four key points for the vision element regarding kids – integer vision effect, functional area design, icon and button design, and font design. For example, children may not understand the

text inside a button but icons can be designed as buttons to show they are clickable.

The work of Michaels [32] and Boyatzis et al. [4] discusses colour preferences of children users as well as the effect of colour on children's emotions. They did colour tests with children around 6 years old, and found that their top three favorite colours are yellow, red, and green. Another type of testing they did was called the story test. If a child heard a happy story, most of them would select yellow. Using this research, they used yellow and red as the gradient colour for the theme colour, and made the whole app look funny and attractive.

Seniors: Boll et al. [3] provide a set of user interface design guidelines for people between 55 to 75 years old. They found 41 participants between 55 and 75 years to fill out questionnaires to research the actual requirement and the problems they have. They used the results to make the user interface design guidelines. According to the guidelines, for font design, the sans serif fonts provide good readability. For colour selection in the main content page, they recommended a light grey background with black fonts. Regarding the size of the icons and the buttons, most of the users reported that the icons are too small, and that double-clicking a small button is a problem for elderly people. The last important thing is the structure of the page. For example, in menu page, a good menu structure helps users to navigate through the user interface more easily. The menu needs to be put in conventional positions to make sure the position of the menus are consistent in the entire software.

Curumsing et al. [10] focus on designing emotion-oriented software, based on the smart home device for elderly. They used extended Goal models, Interaction models, Scenario models, Role models, and Behaviour models to keep track of the "cared for" to a list of emotions. Analysis of these emotions helps developers to understand the expectations of an older adult using the smart home. Using this approach, a goal model for the smart home device was created. The model includes different emotions for the elderly people to help get the elderly people to accept the device and feel like this is what they need. The software can catch the emotion of the user, and analyse their expectations. Thus, the software can make corresponding responses to meet the needs of users. The software can understand users' emotions, this could become one of the determinants of software success.

Curumsing et al. [11] demonstrate a case study of an emergency alarm system for elderly people, presenting the entire suite of models for this case study. They suggested a few important factors on designing the framework and also keeping the interest of the elderly people. Firstly, in order to encourage elderly people to adopt technological solutions, they have to be designed in such a way that they suit the needs of its users, are easy to use, and cost effective. The second important factor determining the successful adoption of technology consists of willingness and enthusiasm for acquiring new knowledge. However, this is rarely the feelings expressed by elderly people when it comes to using a system which is linked with a stigma. For example, some refused to use the pendant because

of its visibility to others. It was viewed as a sign of stigma and old age. These are the way users perceived technology from an emotional aspect.

Wagner et al. [42] explain the impact of age on usability. It states that there is an increase in the average age of internet users which provides evidence that there is a need for catering elderly users for applications. Usability helps organisations by improving the job performance, gaining higher productivity and reduced costs by the users. There are five conceptualisations of age; Chronological or calendar age, Functional or performance-based age, Subjective or psycho social age, Organisational age, and Life span concept of age. Currently, mainly research chronological age is used to allow for consistency and comparison with the existing literature. We have also used chronological age as the other conceptualisations are mostly related to chronological age.

Finally, Holzinger et al. [17] aim to derive metric-based benchmarks for measuring usability. This study suggested two aspects of usability: passive and active interaction. Passive interaction means users are not directly interacting with it, but it helps out in the background. Active interaction means users directly interact with the technology. Several questions were developed to ensure it meets both passive and active interaction. They present an analogy between user anxiety and metrics.

2.2 Modelling emotions of the users

An emotion orientated software development method is developed by Chen et al. [8]. Existing emotion-aware applications lack accuracy in terms of emotion recognition due to the small scale of data collected. Through cloud-based computing and cloud assisted resources, mobiles phones can collect much more data. Combined with the architecture itself, applications can recognise user's emotional changes by big data analysis. Based on the user's current emotion, a common list of feedback is generated in the remote cloud. The information is transferred back to the local cloud, providing users with personalised services. Various in-home devices were used to accommodate the user's emotion.

Miller et al. [33] introduce the People Oriented Software Engineering (POSE) method to capture emotional desires by using emotional goals. The emotional goals are classified into two category of personal emotions and context-specific emotions. A survey is then used to evaluate and compare the proposed emotional model against iStar by implementing two domain models in both iStar and POSE. The survey results show that participants preferred to use POSE models since they are clearer, easier to understand, and not complicated to interpret. Participants mentioned that they were not confident to make modifications to iStar models, and would prefer to modify POSE model if required.

Lopez et al. [27] use personas within emotional scenarios to ensure that emotional desires are met. They describe their experience with three projects in the domains of aged well-being and mental health. Data are gathered form interviews and other ethnographic studies and personas are built based on composing textual description of personality traits. Emotional scenarios are script templates which explore how different personas react in identical situations.

Laurenzi et al. [34] propose a modelling language to support user interactions in heterogeneous physical scenarios. The model helps designers identify the services that will be required by the users to support their activities. It is assumed that systems modelled by this language are structured as Human-centric Wireless Sensor Network (HWSN). The nodes participating in an HWSN can be human-based sensors, regular sensors, mules, witness units and actuators.

Finally, a wire-frame extension method is presented in our previous work [20], to incorporate end-user diverse ages into the design of the software.

2.3 Personas for usability evaluation

Personas provide good information about the ends users the software engineers are designing the software for. Persona has also been used in evaluation of software interface using different usability inspection methods. Burnett et al. [5] reports multiple case studies to evaluate gender inclusiveness in problem solving software using GenderMag (Gender Inclusiveness Magnifier) approach [6]. According to the GenderMag approach they perform cognitive walk-through on three problem solving software from different domains with three personas provided with the GenderMag tool. They could identify gender inclusiveness issues in those software that had been in maintenance for years. They found most problems with the persona Abby that represented one group of users.

McIntosh et al. [30] also reported a study where they evaluated usability of popular e-commerce websites using cognitive walk-through with persona of different age groups. They could identify usability issues in the popular e-commerce websites for the persona representing users who are above 70 years of age. They also applied cognitive walk-through with persona representing users of different age groups. Mendez [31] has proposed a generalised framework called "InclusiveMag" that implements the main concepts of GenderMag approach, however is not focused on gender. InclusiveMag can be used to evaluate inclusiveness issues in any problem solving software with applying cognitive walk-through using persona. We used persona and individual user stories to guide the development of an improved smart parking app [26]. This resulted in a variety of individual user characteristics – age, language, physical and mental challenges, culture – being considered as first class requirements in the design and evaluation of a smart parking app prototype.

In summary there are some some approaches and empirical research evidence of applying cognitive walk-through using persona on problem solving software to conduct usability evaluation.

3 Our Approach

3.1 End-users and Developers Feedback

To evaluate our extended design modelling notation we used a set of different questionnaires, aimed at different classes, i.e., users and developers. We provided multiple solutions to modelling software design decisions regarding human-centric aspects related to age. We wanted to ask target end-users to identify the

ones that are good for the age group, in their opinion. We used a range of target end users from different age groups to evaluate a prototype based on our augmented wire-frame design models. Using their feedback, we checked to see which solutions are the best fit for our prototype use cases.

Our extended wire-frame modelling frameworks are to be used by Software Engineers to create an end-product that is more age-aware and supports different interfaces and interface components for differently-aged end users. We prepared a different set of questions to ask a range of developers their opinion on the new modelling framework. We wanted to identify key current issues that can be found with the pre-existing model frameworks not supporting modelling of end user age. We also wanted their opinion on the new framework and whether it helped them in addressing these issues. Using the questionnaire results, we have refined our extended wire-frame-based design approach to better match the needs of the developers.

3.2 Extended Wire-frames

There were multiple modelling frameworks that could be extended to support end user age difference modelling in our research. We decided that extending wire-frame-based design models would be the best option as most of the changes required for the different age groups were based on the application user interface. wire-frames provide a simple way for developers to create the basic design of an application and our extension point was to create a workflow that a developer can follow for each of the different age groups. In recent years, various other works have looked to extend the use of wire-frame-based UI design and to suggest wire-frame-based designs or partial designs [24, 7]. None have focused on supporting different design decisions based on end user ages.

Based on the research review, our age groups are defined as: *1) Kids*; Under 15 *2) Adults*; Aged between 15 and 64; and *3) Seniors:* Aged above 64. To model different ages, age-related design considerations, and age-related design differences to wire-frame models, we added three features to the original wire-frame modelling framework:

1. Branching (Branch a screen into two or three pathways)
2. Merging (Merging two or three pathways into a single pathway)
3. Splitting (Splitting a screen into multiple screens)

Figure 1 shows an example of branching. A single pathway has been branched into two pathways. This is used when there is a need for different user interface or functionality for the same screen for different aged users. It thus gives developers a tool to express the need for a change in a single screen for different ages.

Figure 2 shows an example of merging. Two pathways have been merged into a single pathway. This is useful when multiple pathways arrive at a specific screen that will be the same for multiple age groups that have been previously branched out. It saves the developers from creating the same screen design for different pathways. It also helps show that multiple screens will be the same across different age groups.

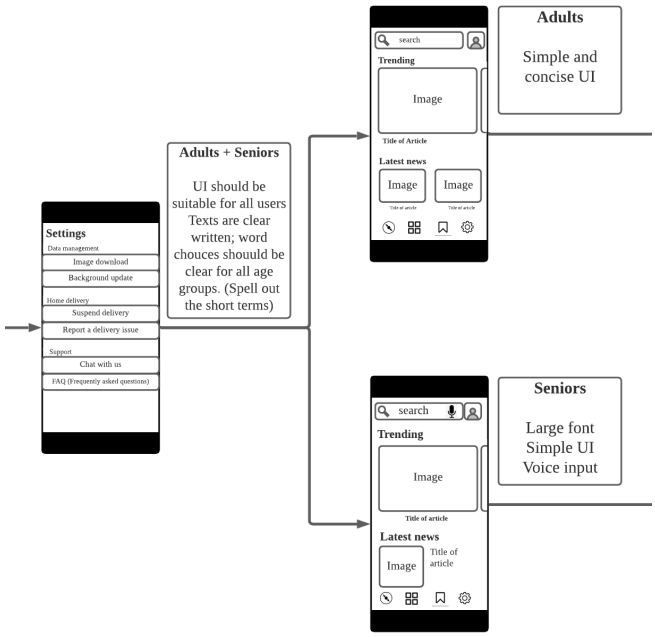


Fig. 1: Example of branching (from [20])

Figure 3 shows an example of splitting. A single screen is split into two screens. This is useful for age groups that require additional assistance in getting a task done. For example, adults may prefer a single register page as it allows them to quickly register. However, kids or seniors may need additional help when registering, e.g. by using a step by step multiple screen approach. Using multiple screens will give developers more room to explain key features within each screen, make items larger, or choose different interaction components. This will be a trade-off between speed and ease-of-use.

4 Evaluation Approach

4.1 Prototype News App

We created a prototype news app based on our extended wire-frame approach to evaluate how easy it was for a developer to use this extended wire-frame model. The prototype was also used to evaluate the final prototype system by different age group target end-users. We chose a news app as the prototype as (i) most age groups use them or are interested to use them; (ii) despite their seaming simplicity, they often have quite complex interfaces and design decisions are not always fitting differently aged users; (iii) the interface design is reasonably detailed but not overwhelmingly so; and (iv) many lessons from news app development can

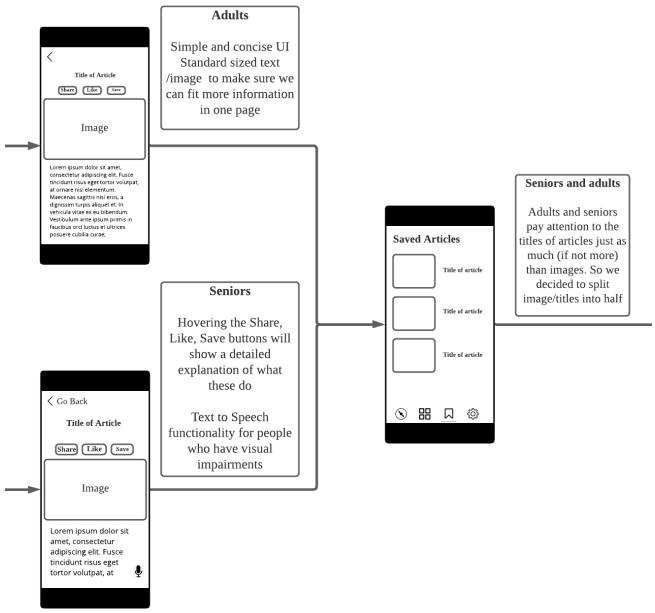


Fig. 2: Example of merging (from [20])

be applied to social media, communications, education and other widely used apps [9]. Hence, the news reading app domain contains enough variation points between the three age groups to try out the use of our extended wire-frame modelling language features.

We used our extended wire-frames to design and develop a Figma-based prototype. The extended wire-frame designed to create the news app prototype is shown in Appendix. By using the extended modelling framework we captured key human-centric aspects regarding the age of the users and designed solutions to accommodate these. This news application has different functionality and user interface for different age groups of its users. In this prototype, we decided to keep the colours for each of the branches specific to the age groups even if a screen was for all three user types. For example, a screen that has not been branched out which is used for all three user types will still have different colour themes to allow for a more consistent experience for the end user.

In the extended wire-frame design model, we have many common pages for all three age groups. We needed to find a balance point for these age groups such as use of font size, user interface complexity, and any related points to ensure that the design for the common pages is clear enough for use from all three age groups. An age selector is presented to users at the start, as shown in Figure 4.

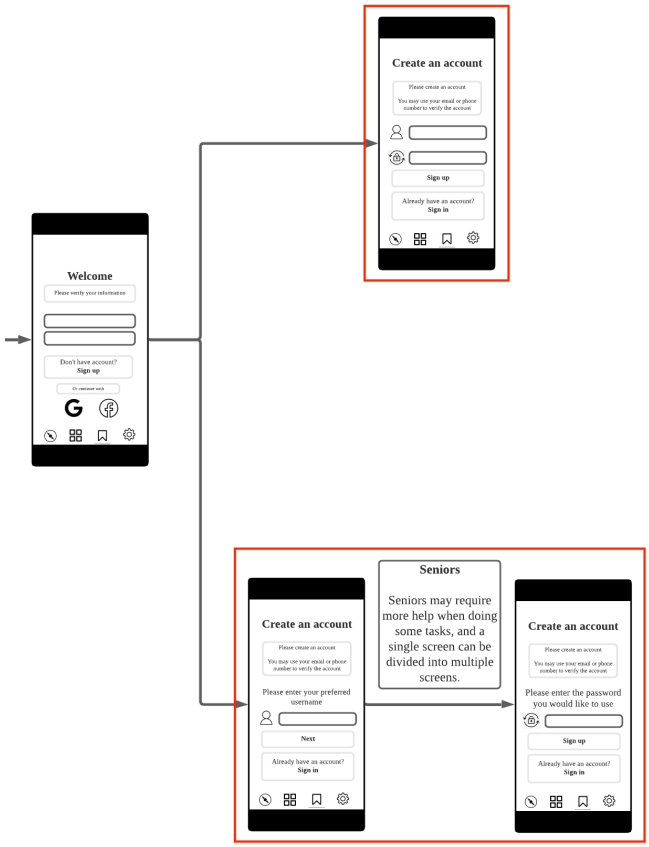


Fig. 3: Example of Splitting (from [20])

Children For the **kids application**, the key aim was to make the application enjoyable and attractive enough for the children. Some user interface design decisions that needed to be considered are:

- *Colour:* Research showed that children prefer colours like red and yellow and thus we used a rainbow gradient colour schema to catch the eyes of the children.
- *Font Style:* Use a fun looking font size to help children stay focused.
- *Icon selection:* We chose a more cartoonish icon for children to cater for their shorter attention span.

Figure 5a shows a user interface designed for kids, based on that specified in our extended wire-frame.

Adults For the **adult application**, the key aim was to make the app clear and simple so that they will be able to quickly navigate between pages without too

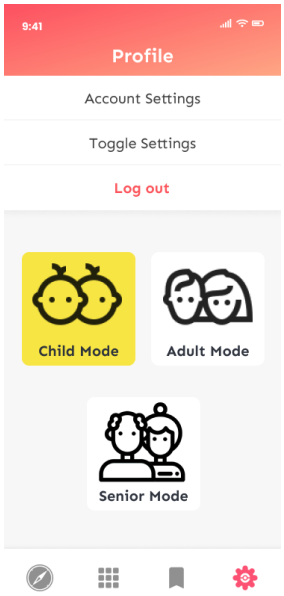


Fig. 4: Age category selection page (from [20])

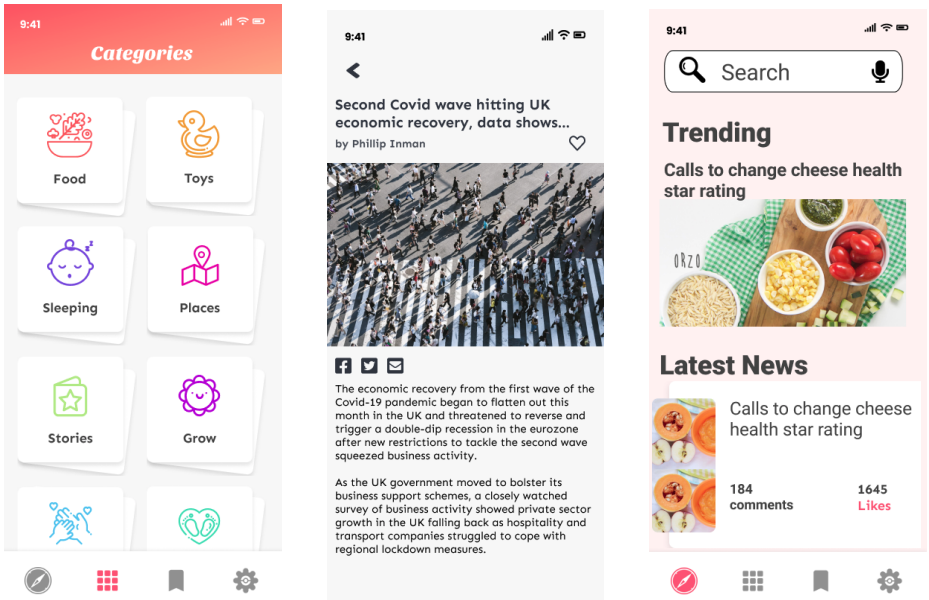
much overhead information. Thus key design decisions for the adult app user interface design included:

- *Font Size:* Normal size
- *Colour:* Simple and conventional colours. More professional compared to the kids version.

Figure 5b shows a user interface designed for adults, using our extended wire-frame.

Seniors The **senior application** is similar to the adult application, but we needed to make sure that everything is large enough, easily accessible, and that the user interface is simple enough. We added some additional functionality to help aid seniors so that they can comfortably use aspects of the technology that they may not be familiar with. Some key design decisions for the senior age group include:

- *Colour:* Similar to adults, use simple and conventional colours.
- *Font Size:* use a larger font size to aid visual impairments.
- *Voice control:* Senior users may have trouble typing on a mobile device or reading smaller font sizes and speech-to-text and text-to-speech functionality would be good for them.
- *Larger components:* Make items such as buttons, and links large enough for them to easily click.



(a) Kids version (b) Adults version (c) Seniors version

Fig. 5: User interfaces adapted from the extended wire-frames (from [20])

Figure 5c shows a user interface designed for seniors, using our extended wire-frame.

We also provided a toggle setting, shown in figure 10, so that users can customise the app styles such as the font size, font style, etc. This was necessary because there may be some users who do not require the customisations that were categorised within their user age groups. Other customisations that were determined necessary during our research are specified in the extended wire-frames. This allows developers to choose whether to include a customization within their applications.

4.2 Usability Evaluation

To evaluate the news app prototype's usability, a usability test was conducted to gain insights into what went well and what needs to be improved in our extended wire-frame modelling approach. Users were asked to complete two tasks:

- Change the user mode along with some settings to match their preferences; and
- Find an article they are interested in, save the article, and open the article again using the saved articles page.

The details of the tasks given to the users were purposely given without too much detail on how to navigate within the application. This was so that we can

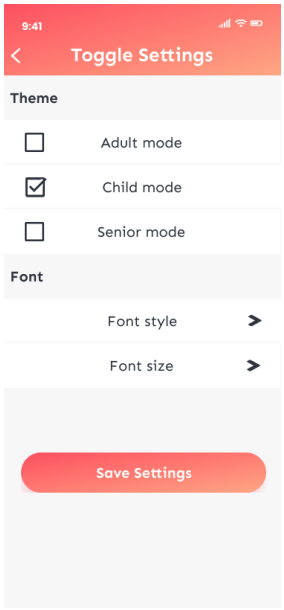


Fig. 6: Toggle setting (from [20])

see how a new user will act when using this application. These tasks helped us to gather user data on key age-based design decisions in the news app:

- Whether each user type is able to use the interaction flow designed for them within the application, as well as change the settings to match their accessibility needs; and
- whether the navigation supported within the application is easily understandable to new users.

The testers were asked to record whether the tasks were successfully completed as well as to describe any troubles that they encountered during performing the tasks. We conducted a preliminary test, and using the results, we enhanced our extended wire-frame models to increase the usability of the prototype. We plan to conduct a more comprehensive usability evaluation with developers to evaluate whether the extended wire-frame is applicable to different domains and can be easily used to create prototypes. We also plan to conduct usability evaluations with end-users from various age-groups to evaluate whether the created prototype actually increased the usability of the news app prototype for each age group.

4.3 Cognitive Walk-through using Personas

In order to evaluate our extended wire-frame designs we applied a cognitive walk-through process [39]. Cognitive walk-through is a popular usability inspection method that includes performing some specific tasks on the design or the

user interface itself by an evaluator in order to assess the usability of the interface or the design. User characteristics are taken in to consideration while performing the walk-through. This is often done with user personas. Personas are archetypal descriptions of users that include their goals, general characteristics, pain points and any other information. In our cognitive walk-through approach we use some user personas and evaluate our wire-frame while accomplishing set tasks.

According to Wharton et al. [43], we need to define the cognitive walk-through process before conducting the walk-through. They also advise to record all critical information while walking though and later analysing those. In the first step Wharton et al. [43] advise to define who the users are, what the tasks they will perform, what is the design or interface they will perform the tasks on and the sequence of actions needed to accomplish the task. Since we want to evaluate our wire-frame design, the interface would be the wire-frame. The wire-frame is designed particularly for users of different age groups. We collect personas of different age group from a search in the existing literature.

Collection of Personas Creating new personas for the evaluation of the wire-frame is out of scope for this study. We searched for existing personas representing end users of different age groups in the existing literature. We searched with "elderly persona", "children persona" and "persona of news app?" on Google scholar and looked into the published research that describe personas. We then reviewed the quality of the persona and how the persona is created. Based on our reviews we selected three personas – one child, one senior and one adult persona. We will use these three personas in the cognitive walk-through process.

Children persona: We collected children persona from [35]. This article was found while searching for children persona. The article focuses on persona creation for children and elderly end users. They describe different factors that can influence the decision of adopting a qualitative, quantitative or mixed method for data collection for creating personas. They provide several case studies as example. One of the case studies describe a project called "FamCannector", where they have created some children persona. We take the persona called Sarah, as shown in Figure 7, who is an eight years old school girl who uses computers for didactic games and information seeking. She often needs help using the system. We believe she represents the children end users for our news app wire-frame.

Adult Persona: Mayas et al [29] describes the opportunities and challenges of personas from several projects. They present an example persona Michael, as shown in Figure 8, who is a 34 years old consultant. He is a commuter and a frequent traveller. We take his persona as an adult persona as commuters often read news during their travel.

Senior Persona: We collected one senior persona from [25]. The article reports a survey to understand elderly end users of mobile devices and to identify the factors that influence their interaction. They presented three personas with different level of literacy and interaction. We selected the persona Manoel, shown in Figure 9 among those. Manoel enjoys using computing devices, however is reluctant to spend much time learning new things. He often struggles with the

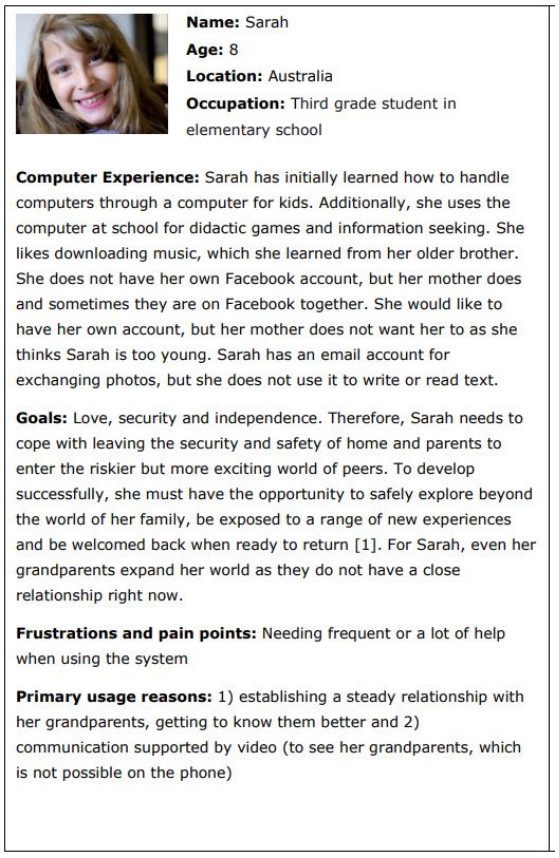


Fig. 7: Children persona collected from [35]

font size. Since the other two personas do not use computing devices frequently, we think Manoel will best represent the senior end users for our news app wire-frame.

Usability Tasks In order to perform the cognitive walk-through we need to define some usability inspection tasks that we assume the selected personas perform using the prototype app. We define the following two tasks that we will perform on the prototype app:

- Task 1: User can change the font size from settings: For this task we assume that the user will be able to bring the setting interface and customise their font size.
- Task 2: User can search for desired news article: For this task we assume that the user can perform a keyword based news search on the prototype app interface.

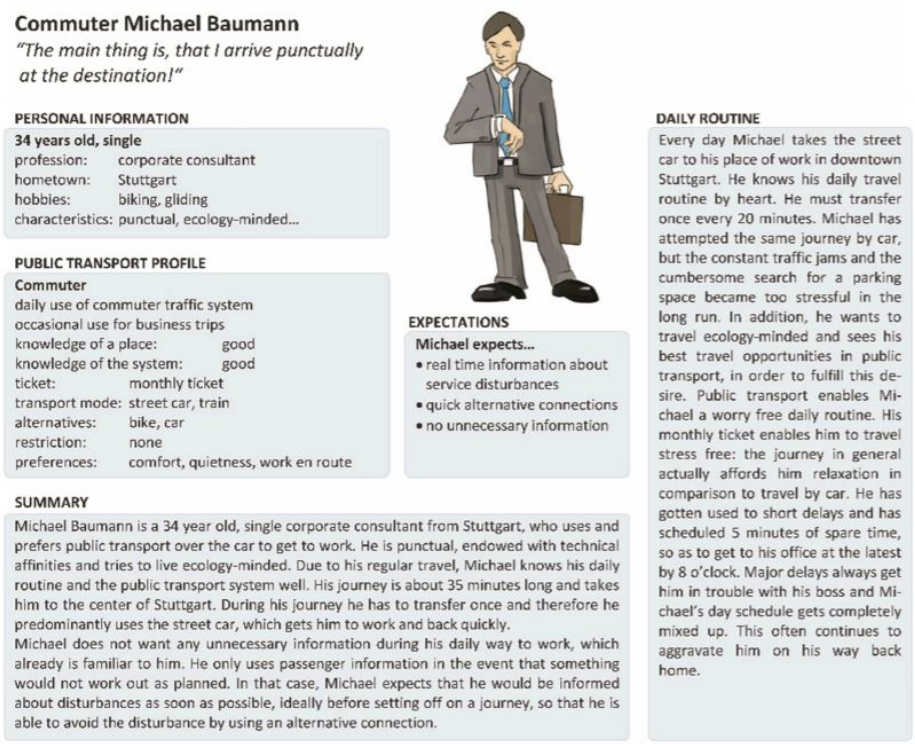


Fig. 8: Adult persona collected from [29]

Fig. 9: Senior persona collected from [25]

5 Results

In this section, we present the results of our survey of developers and users, and the cognitive walk-throughs using personas. We collected a total of 27 responses

– 6 from developers, 21 from app end users. We also conducted the cognitive walk-throughs by three personas: one child, one adult, and one senior.

5.1 Evaluation Results - Developer questionnaires

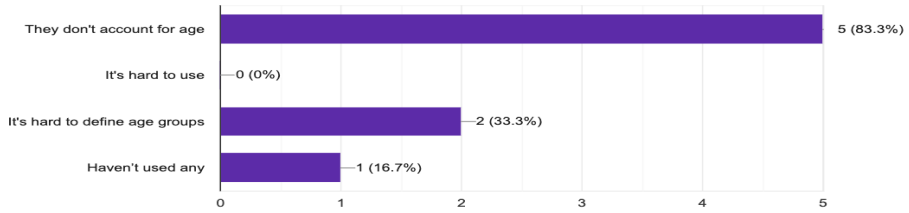


Fig. 10: Developer responses on designing in issues regarding different end user age during development (from [20])

Six developers responded to our survey – 3 with 5 to 10 years development experience, 2 with 1 to 4 years, and 1 with more than 20 years of experience. Among all of these developers, 4 said they think there is a need for human-centric aspects regarding age in modelling frameworks e.g UML diagrams, Wire-frames, User stories, etc. One had never thought of this issue, and one thought it is not important. We collected a list of approaches and frameworks they currently use to deal with age related issues of the users in the software that they develop. This included use of wire-frames (3 of the developers), UML (3), user stories (2), use cases (2), and BPMN diagrams (1).

We asked the 6 developers whether they have encountered any issues regarding age during software development. Based on their responses, as shown in figure 10, one of the key issues is that the majority of developers do not address differing age of their end users at all in their software development. To address this issue in this study, we captured a lot of end user requirements from our end user survey questionnaires. The second issue is that some developers believe it is hard to define an "age group". To address this, we decided to research more about the target audience of the particular software and then defined the age groups accordingly.

We asked developers what tool(s) they used to help them address differing age issues of their app and web site end users. They mostly stated they never used any tools. Some suggested that although they did not use any tools in particular, they tried to address age related problems such as security restrictions in the identity server (e.g. some websites are for adults only); and informally captured non functional requirements in text, annotate the odd use case/user story. For a news application, age selection is important to restrict inappropriate news from the children. Icons, text, and background colours might also need to be changed

to accommodate different types of users sight limitations and preferences based on their age.

Regarding what other human-centric aspects they think could be a good addition to better support in software modelling frameworks, developers included gender, culture, end user language, physical and mental challenges of users, accessibility needs of end users, Convenience of usage, usability test (user test), cognitive load (mental effort) test (including performance measures in terms of user's response time taken to complete a task and its accuracy, or physiological measures, e.g. pupil dilation and blink rate).

5.2 Evaluation Results - End-user survey

We received 21 responses, 13 from 18-25 (Young Adults) respondents, 6 from 26-49 (Adults), and 2 from those 50-64 years old. The age demographics for the questionnaire participants are mostly young adults with ages ranging from 18 to 25. We did not have any younger participants (below 18) and senior participants (above 65). Most of the participants used technology for daily activity for a significant amount of time (8 hours+). A majority of the participants found that using technology is easy for them (14 people said they are proficient with it, five said they are good with it, and one said they are doing okay with it). We also found out that the most popular device is a smartphone used for social media, entertainment and news apps. We asked if any participant had any accessibility requirements. The majority of people saying they had visual impairments, such as needing glasses to read, having short sight, and one person answered that they needed to use voice output to "read" app text.

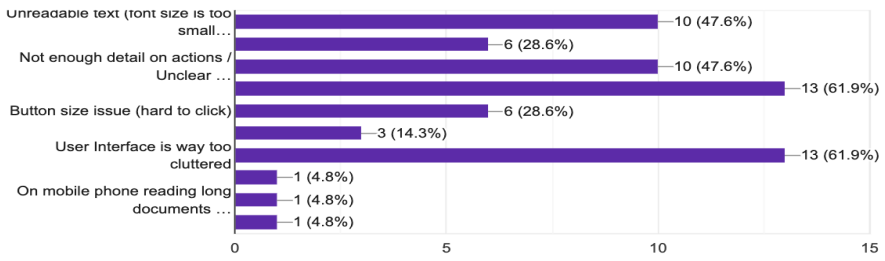


Fig. 11: Key pain points of using software systems (from [20])

5.3 Evaluation Results - Cognitive walk-through

We performed cognitive walk-throughs on our news prototype app with the selected personas representing children, adult and senior users. We evaluated the usability of the news prototype app by performing the defined usability

tasks as the persona. The cognitive walk-through is performed by one of the authors. Table 1 and 2 present the results of our cognitive walk-through process for the tasks defined in Section 4.2.

In our usability evaluation using cognitive walk-through with child persona "Sarah" we found evidence for all the related works summarised in Section 2. We used the colour theme advised by Michaels [32] and Boyatzis et al. [4] and found that the interface was intuitive for Sarah. We used icons for buttons as advised by [36] and made the title texts and clickable button distinguishable according to [28]. We found that Sarah could find the icons easily and could successfully conduct a search for news article using the search option. She could complete the usability tasks without help from others. We have implemented background colour and font suggestions provided by Boll et al. [3]. In our usability evaluation with senior persona "Manoel", we found that the font was suitable for him. In the description of "Manoel" persona we found that he prefers fonts bigger in size on mobile devices.

Table 1: Cognitive walk-through with selected personas - Usability task 1: Change the font size

Persona	Cognitive walk-through	Notes
Children persona - Sarah	Opens news app wire-frame After signing in she lands on the "KidsNews" page. There is no option on this page to change the font size. She explores the four options available at the bottom. She finds the "profile" page where the second options says "Toggle Settings". She selects that and finds the option for "font size".	Sarah can complete the task without any help from others. The theme is intuitive and easy for Sarah to explore and find the functionalities.
Adult persona	Opens news app wire-frame After signing in she lands on the "News" page. Although the font size is good for him, he often needs to make the fonts bigger while he reads news while travelling on public transport. He clicks on the settings icon, and finds the toggle settings option. He takes the short cut and selects senior mode presents the text in bigger font size. He likes the fact that he can change the settings with very fewer clicks and while on the move.	Michael can change the font from toggle setting or can switch account settings to make the font bigger. He likes that he can do this with minimum effort on the app.
Senior persona - Manoel	Opens news app wire-frame After signing in he lands on the "News" homepage. He likes the fonts since those are bigger than usual. He wants to play with the font size. He goes to profile page and checks "adult mode" and "child mode". He finds that fonts are smaller for adults. He goes to "Toggle Settings" and changes the font size for his profile to smaller as adult mode.	Manoel can easily check all the font size options available on the app wire-frame and can change the font size for his profile.

Table 2: Cognitive walk-through with selected personas - Usability task 2: Search for news article

Persona	Cognitive walk-through	Notes
Children persona - Sarah	Opens news app wire-frame After signing in she lands on the "KidsNews" page. She wants to read the article about "calls to change cheese" that she heard from her friend. She likes the small categories icon at the bottom left of the screen. She finds it easy to select food since this is shown as a category on the main screen. She selects the category and finds all the articles related to food. She quickly finds the search icon at the top right and searches for the particular news she was looking for. She can find it easily.	The interface layout and the options are intuitive and easy for children to figure out common functionalities.
Adult persona	Opens news app wire-frame After signing in he lands on the "News" homepage. He writes his preferred keywords to search for news he enjoys to read. He does not have any difficulty in looking for the search options.	The search option on top of the homepage is easy to locate.
Senior persona - Manoel	Opens news app wire-frame After signing in he lands on the "News" homepage. He does not like the trending news that is highlighted on his homepage. He likes to read about sports so he clicks on the categories to find other categories of news. He finds "sports" category and selects that to find more on sports. He searches for the articles on yesterday's match by clicking top right search icon.	The interface is designed in a way that the common functionalities can be found easily.

Based on the cognitive walk-through, we made the following findings about the user interface.

- The user interface is easy for children and intuitive enough that they are happy to explore and find functionalities they desire without help from others
- The user interface is easy for senior users who prefer larger fonts as well as for others who prefer normal fonts - they can toggle the setting very easily

5.4 Discussion

From the result in figure 11 we can see that most of the problems are User Interface related issues. This is one of the main reasons we decided to extend wire-frames since wire-frames provide early visuals that can help with these problems, they are also easy to adapt compared to conceptual designs. We used questionnaires for collecting data. We created both end user and developer questionnaires to capture data from multiple angles. We got a range of feedback from different age groups that indicated usability enhancement in the prototype news app for different age groups of target end users. However, we need to recruit more participants to gain a larger sample size, especially younger (under 18) and older (over 65) end users. According to our survey results in figure 12, we can see that our participants are commonly using a range of different application domains such as social, entertainment, study, etc. These results helped us

in deciding on which domain our example extended wire-frame and prototype would focus on. Generalising our experiences to those other common domains would help to show if the approach can enhance different age group usability for them as well.

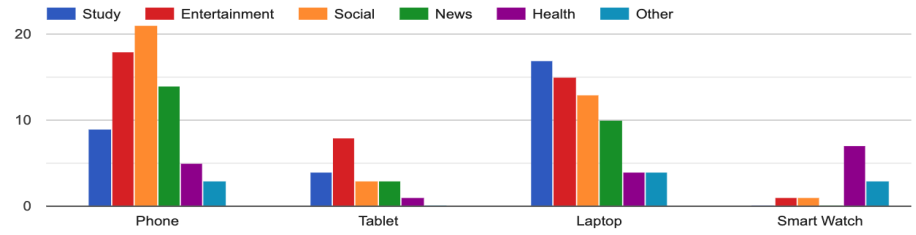


Fig. 12: Devices used by participants and for what purposes (from [20])

We chose to extend wire-frame design models with information about the age of target end users and alternative user interface design decisions based on these ages. However, other modelling frameworks such as interaction and sequence diagrams may help developers understand the human-centric aspects regarding age further and use similar approaches based on the wire-frame extensions we have created. For example, figure 13 contains an interaction diagram that is adapted from the extended wire-frames presented in this paper. Adapting other human-centric aspects, such as gender, emotion, and physical support, into the extended modelling framework presented in this paper may also be beneficial. Additional research can be done to increase the range of our user types and changes to the designs to accommodate their needs. Using approaches developed in the accessibility research field could also help us to better understand the needs of users with a range of disabilities. The specific requirements of these user types need to be identified so that the developers can create an appropriate pathway and design decisions for those users in our extended wire-frame models.

6 Summary

In this paper, we discuss the need for incorporating human-centric aspects into modelling frameworks in order to make software suitable for diverse end users. We reviewed the existing modelling frameworks, and found they mostly do not support modelling the age of end users. The existing modelling and design frameworks do not provide different design solutions for different age groups according to the specific needs of end users. We developed a set of extensions to the commonly used wire-frame modelling approach to incorporate different designs for child, adult and senior end users. Evaluation of our modelling approach

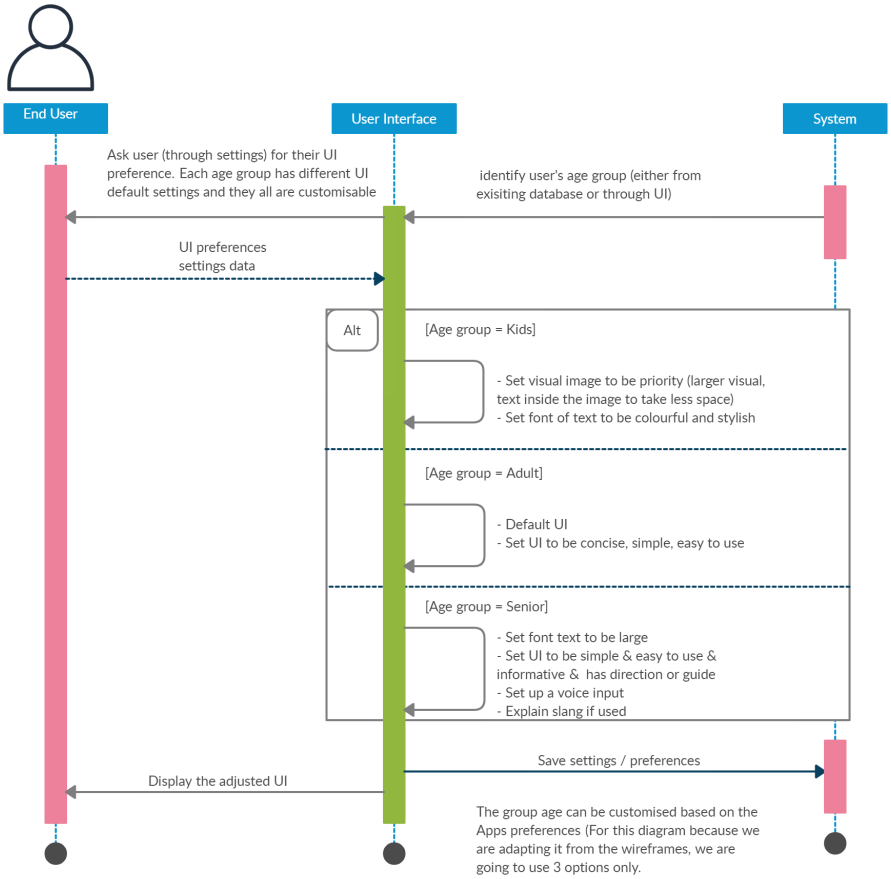


Fig. 13: Interaction diagram adapted from the extended wire-frames (from [20])

with developers and a prototype news app developed using our approach with a range of differently aged end users are represented. We conducted cognitive walk-throughs with three personas representing children, adults and seniors to evaluate the usability of the prototype app. Our future work includes incorporating other human-centric aspects e.g. gender, culture, and language into the extended wire-frame model. Another future direction is to try the same model extension approach in other modelling frameworks, such as user stories, use cases, and sequence diagrams.

ACKNOWLEDGEMENTS

Support for this work from ARC Laureate Program FL190100035 is gratefully acknowledged.

References

1. Alves, T., Natálio, J., Henriques-Calado, J., Gama, S.: Incorporating personality in user interface design: A review. Personality and Individual Differences **155**, 109709 (2020)
2. Australian Bureau of Statistics: Australian demographic statistics, jun 2019. https://www.abs.gov.au/ (2019)
3. Boll, F., Brune, P.: User interfaces with a touch of grey?–towards a specific ui design for people in the transition age. Procedia Computer Science **63**, 511–516 (2015)
4. Boyatzis, C.J., Varghese, R.: Children's emotional associations with colors. The Journal of genetic psychology **155**(1), 77–85 (1994)
5. Burnett, M., Peters, A., Hill, C., Elarief, N.: Finding Gender-Inclusiveness Software Issues with GenderMag: A Field Investigation, p. 2586–2598. Association for Computing Machinery, New York, NY, USA (2016), https://doi.org/10.1145/2858036.2858274
6. Burnett, M., Stumpf, S., Macbeth, J., Makri, S., Beckwith, L., Kwan, I., Peters, A., Jernigan, W.: GenderMag: A Method for Evaluating Software's Gender Inclusiveness. Interacting with Computers **28**(6), 760–787 (10 2016). https://doi.org/10.1093/iwc/iwv046, https://doi.org/10.1093/iwc/iwv046
7. Chen, J., Chen, C., Xing, Z., Xia, X., Zhu, L., Grundy, J., Wang, J.: Wireframe-based ui design search through image autoencoder pp. 1–31 (2020)
8. Chen, M., Zhang, Y., Li, Y., Mao, S., Leung, V.C.: Emc: Emotion-aware mobile cloud computing in 5g. IEEE Network **29**(2), 32–38 (2015)
9. Constantinides, M., Dowell, J., Johnson, D., Malacria, S.: Exploring mobile news reading interactions for news app personalisation. In: Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services. pp. 457–462 (2015)
10. Curumsing, M.K., Fernando, N., Abdelrazek, M., Vasa, R., Mouzakis, K., Grundy, J.: Emotion-oriented requirements engineering: A case study in developing a smart home system for the elderly. Journal of Systems and Software **147**, 215–229 (2019)
11. Curumsing, M.K., Lopez-Lorca, A., Miller, T., Sterling, L., Vasa, R.: Viewpoint modelling with emotions: a case study. International Journal of People-Oriented Programming (IJPOP) **4**(2), 25–53 (2015)
12. Dalpiaz, F., Franch, X., Horkoff, J.: istar 2.0 language guide. arXiv preprint arXiv:1605.07767 (2016)
13. El-Attar, M., Luqman, H., Karpati, P., Sindre, G., Opdahl, A.L.: Extending the uml statecharts notation to model security aspects. IEEE Transactions on Software Engineering **41**(7), 661–690 (2015)
14. Goncalves, E., Castro, J., Araujo, J., Heineck, T.: A systematic literature review of istar extensions. Journal of Systems and Software **137**, 1–33 (2018)
15. Grundy, J., Khalajzadeh, H., Mcintosh, J.: Towards human-centric model-driven software engineering pp. 229–238 (2020)
16. Grundy, J., Patel, R.: Developing software components with the uml, enterprise java beans and aspects. Proceedings 2001 Australian Software Engineering Conference pp. 127–136 (2001)
17. Holzinger, A., Searle, G., Kleinberger, T., Seffah, A., Javahery, H.: Investigating usability metrics for the design and development of applications for the elderly. In: International Conference on Computers for Handicapped Persons. pp. 98–105. Springer (2008)

18. Hussain, A., Abd Razak, M.N.F., Mkpojiogu, E.O., Hamdi, M.M.F.: Ux evaluation of video streaming application with teenage users. Journal of Telecommunication, Electronic and Computer Engineering (JTEC) **9**(2-11), 129–131 (2017)
19. Iung, A., Carbonell, J., Marchezan, L., Rodrigues, E., Bernardino, M., Basso, F.P., Medeiros, B.: Systematic mapping study on domain-specific language development tools. Empirical Software Engineering **25**(5), 4205–4249 (2020)
20. Jim, A.Y., Shim, H., Wang, J., Wijaya, L.R., Xu, R., Khalajzadeh, H., Grundy, J., Kanij, T.: Improving the modelling of human-centric aspects of software systems– a case study of modelling end user age in wirefame designs. Evaluation of Novel Approaches to Software Engineering (ENASE) (2021)
21. Kamalrudin, M., Grundy, J., Hosking, J.: Maramaai: tool support for capturing and managing consistency of multi-lingual requirements pp. 326–329 (2012)
22. Kulyk, O., Kosara, R., Urquiza, J., Wassink, I.: Human-centered aspects. In: Human-centered visualization environments, pp. 13–75. Springer (2007)
23. Kulyk, O., Kosara, R., Urquiza, J., Wassink, I.: Human-centered aspects. In: Human-centered visualization environments, pp. 13–75. Springer (2007)
24. de Lange, P., Nicolaescu, P., Rosenstengel, M., Klamma, R.: Collaborative wireframing for model-driven web engineering pp. 373–388 (2020)
25. Leme, R.R., Amaral, A.R., Zaina, L.A.M.: Interaction with mobile devices on social networks by elderly people: A survey in brazil with facebook. In: 2014 XL Latin American Computing Conference (CLEI). pp. 1–7 (2014). https://doi.org/10.1109/CLEI.2014.6965103
26. Li, C., Yu, Y., Leckning, J., Xing, W., Fong, C., Grundy, J.C., Karolita, D., McIntosh, J., Obie, H.: A human-centric approach to building a smarter and better parking application. In: 2021 IEEE International Conference on Computers, Software, and Applications Conference (COMPSAC2021), July 12-16 2021, online. IEEE (2021)
27. Lopez-Lorca, A.A., Miller, T., Pedell, S., Mendoza, A., Keirnan, A., Sterling, L.: One size doesn't fit all: diversifying" the user" using personas and emotional scenarios. In: Proceedings of the 6th International Workshop on Social Software Engineering. pp. 25–32 (2014)
28. Masood, M., Thigambaram, M.: The usability of mobile applications for preschoolers. Procedia-Social and Behavioral Sciences **197**, 1818–1826 (2015)
29. Mayas, C., Hörold, S., Krömker, H.: Personas for requirements engineering. In: Ebert, A., Humayoun, S.R., Seyff, N., Perini, A., Barbosa, S.D. (eds.) Usability- and Accessibility-Focused Requirements Engineering. pp. 34–46. Springer International Publishing, Cham (2016)
30. McIntosh, J., Du, X., Wu, Z., Truong, G., Ly, Q., How, R., Viswanathan, S., Kanij, T.: Evaluating age bias in e-commerce. In: 2021 IEEE/ACM 13th International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE). pp. 31–40 (2021). https://doi.org/10.1109/CHASE52884.2021.00012
31. Mendez, C.: The inclusivemag method: A start towards more inclusive software for diverse populations (2020)
32. Michaels, G.M.: Colour preference according to age. The American Journal of Psychology **35**, 79–87 (1924)
33. Miller, T., Pedell, S., Lopez-Lorca, A.A., Mendoza, A., Sterling, L., Keirnan, A.: Emotion-led modelling for people-oriented requirements engineering: the case study of emergency systems. Journal of Systems and Software **105**, 54–71 (2015)
34. Monares, Á., Ochoa, S.F., Herskovic, V., Santos, R., Pino, J.A.: Modeling interactions in human-centric wireless sensor networks. In: Proceedings of the 2014

IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD). pp. 661–666. IEEE (2014)
35. Moser, C., Fuchsberger, V., Neureiter, K., Sellner, W., Tscheligi, M.: Revisiting Personas: The Making-of for Special User Groups, p. 453–468. Association for Computing Machinery, New York, NY, USA (2012), https://doi.org/10.1145/2212776.2212822
36. Pan, X.: Research of iphone application ui design based on children cognition feature. In: 2010 IEEE 11th International Conference on Computer-Aided Industrial Design & Conceptual Design 1. vol. 1, pp. 293–296. IEEE (2010)
37. Parker Software: Key considerations for making age-friendly software. https://www.parkersoftware.com/blog/key-considerations-for-making-age-friendly-software/ (2019)
38. Pew Research Center: Internet, Science & Tec: Internet/broadband fact sheet. https://www.pewresearch.org/internet/fact-sheet/internet-broadband/ (2019)
39. Polson, P.G., Lewis, C., Rieman, J., Wharton, C.: Cognitive walkthroughs: a method for theory-based evaluation of user interfaces. International Journal of Man-Machine Studies **36**(5), 741–773 (1992). https://doi.org/https://doi.org/10.1016/0020-7373(92)90039-N, https://www.sciencedirect.com/science/article/pii/002073739290039N
40. Spichkova, M., Zamansky, A., Farchi, E.: Towards a human-centred approach in modelling and testing of cyber-physical systems pp. 847–851 (2015)
41. Statistic Canada: Age categories, life cycle groupings. https://bit.ly/3dopioH (2017)
42. Wagner, N., Hassanein, K., Head, M.: The impact of age on website usability. Computers in Human Behavior **37**, 270–282 (2014)
43. Wharton, C., Rieman, J., Lewis, C., Polson, P.: The cognitive walkthrough method: a practitioner's guide (1994)