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Tablet-Applications for the Elderly: Specific Usability Guidelines

Master‘s Thesis at Ulm University

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Abstract

While the world population is aging, the technological progress is steadily increasing. Smartphones and tablets belong to a growing market and even more people aged 65 and above are using such touch devices. However, with advancing age normal cognitive, sensory, perceptual and motor changes influence psychological and physical capabilities and therefore the way the elderly are able to use tablet-applications. When designing tablet-applications for the elderly developers have to be supported in understanding these capabilities. Therefore, this thesis provides a comprehensive compilation of usability guidelines in order to develop user-friendly tablet-applications for older people. The development and testing of an exemplary tablet-application within this thesis shows how these guidelines can be brought into practice and how this realization is evaluated by test persons in this age group.

Acknowledgment

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Contents

1 Introduction

Usability guidelines are provided with the intention to give developers an overview and a sense for those issues which affect humans when using a computer system in general. Within this work specific usability guidelines are proposed, which mainly focus on facilitating the use of tablet-applications especially for the elderly. A more detailed view on the motivation, objective and thesis structure is provided within the following sections.

1.1 Motivation

The world population is aging and current estimations predict that the share of people aged 65 and above is still increasing in future. While currently 8% of the total global population are aged 65 and older, in year 2025 this share of the population will be 11% and 16% in year 2050 [Statista, Inc., 2010]. The reasons for this trend is on the one hand the higher life expectancy due to the improved medical and hygienic standards, on the other hand the declining birth rate [National Institute on Aging, 2011]. With advancing age normal cognitive, sensory, perceptual and motor changes influence psychological and physical capabilities. Therefore, significant differences between younger and older people exists regarding the way they think, act, react and move.

While the society is getting older, the technological progress and development of computer based systems is steadily increasing. Considering merely touch based devices, smartphones and tablets belong to a growing market. Even more people aged 65 and older are using smartphones or tablets and therefore are a viable and growing user group. In 2013 18% of people aged 65 and older (in the United States) owned a tablet, compared to 13% in 2012 and 7% in 2011 [Statista, Inc., 2013]. Due to their screen size, especially tablets are suitable mobile devices for the elderly offering various supportive and practical applications. When this large variety of applications should be accessible for the elderly, age related changes have to be considered more attentive in application development.

1.2 Objective

Previous research exists which focuses on usability guidelines for the elderly concerning web design [Holt, 2000, Kurniawan and Zaphiris, 2005] and the design of products in general [Farage et al., 2012, Fisk et al., 2009]. In addition, several authors present and propose design recommendations specifically for touch screen devices for older people [Caprani et al., 2012, Al-Razgan et al., 2012, Loureiro and Rodrigues, 2014, Boustani, 2010]. However, these guidelines are either not reasoned sufficiently which makes it difficult to realize their intention, or they are derived from web design guidelines and therefore do not show special regards to interactive issues of touch devices.

Therefore, the aim of this thesis is to provide a comprehensive compilation of usability guidelines in order to develop user-friendly tablet-applications especially for older people. Each guideline and its medical or psychological background is discussed in detail. In this way, application developers and designers are supported in understanding the capabilities of the elderly resulting in effectively applied guidelines.

1.3 Structure of this Thesis

Within this thesis, specific usability guidelines are presented which compensate age-related physical and cognitive declines and therefore lead to user friendly tablet-applications for the elderly. At first, a brief overview of general usability aspects is given in chapter 2 (irrespective of age). Furthermore, age-related cognitive and physical changes are described in order to provide a better understanding of the abilities and impairments of the elderly. The influence of these changes on the appropriateness of touch devices (tablets in particular) and application types are discussed. In chapter 3 literature based usability guidelines are derived and their significance substantiated with medical and psychological facts. In order to investigate how these guidelines may be applied and in which way this implementation actually supports the elderly, an exemplary application is developed as a part of this thesis. This application is described in chapter 4. In addition, a usability test is conducted in order to collect and evaluate the opinions of elderly participants and record observations on how they use this application (cf. chapter 5). Finally, essential aspects concerning the usability guidelines from chapter 3 as well as findings and conclusions regarding the usability test are summarized and discussed in chapter 6.

2 Fundamentals

This chapter introduces fundamentals and issues required for a comprehensive understanding of this thesis. Therefore, section 2.1 defines the term “Usability” and the criteria an user interface has to satisfy to be user-friendly. Since this work focuses on a specific user group of people older than 64 years, the physical and cognitive impairments increasing with age are summarized in section 2.2. Furthermore, the guidelines proposed in this work concentrate on the development of tablet-applications, which provide different ways of interaction as, for example, a Laptop or a PC. Thus, the advantages of touch devices especially for elderly are pointed out in section 2.3. Finally, section 2.4 describes what kind of tablet- or smartphone-applications the elderly use and which expectations they have towards these applications.

2.1 Usability

The usability of a computer system describes the quality of how well a user is able to access the provided functionality. This quality is influenced by the factors whether the user can accomplish a certain intended task efficiently, effectively and satisfyingly. Five important attributes of usability are given by Nielsen [1994]:

Learnability: The system should be easy to learn for a user.

Efficiency: The system should allow user to reach an intended goal within a reasonable amount of time (i.e., the productivity of the system should be at a high level).

Memorability: The system should be easy to remember. A user who has not used the system over a long period of time should relearn to use the system with minimal effort.

Errors: The system should prevent the user from making errors and offer the user the opportunity to easily recover from them (if occurring nevertheless). Fatal errors must not occur.

Satisfaction: The system should be pleasant to use. Frustration, fatigue or dissatisfaction should not be induced.

Thus, the aim of developing a user-friendly computer system is to fulfill these aspects as far as possible. Usability guidelines lead developers towards such a user-friendly system by giving an overview and a sense for issues which affect humans in using a computer system.

Since age-related impairments influence the way people use computer systems, the five aspects named above have to be considered from a different point of view. As an example, a system which is easy to learn for a twenty-year old is not automatically easy to learn for a 68-year old as well. Hence, this system would be less user friendly to the elderly. Physical and cognitive impairments which often occur with advancing age influence the way of fulfilling usability aspects. These impairments are described in detail in the following section.

2.2 Characteristics of Aging

In order to elaborate and understand specific usability guidelines especially for the elderly it is inevitably to understand how age influences the way people think, act, react and move and how a user-friendly system can be developed despite the presence of age-related impairments. Thus, this section gives an overview of the age-related declines in physical and cognitive capabilities. This contains the description of impairments concerning sensation and perception (e.g., vision) in section 2.2.1, cognition in section 2.2.2 as well as mobility in section 2.2.3. Figure 2.1 illustrates these issues at a glance. Chapter 3 describes how such declines influence the development of applications for the elderly in detail and how these can be compensated.

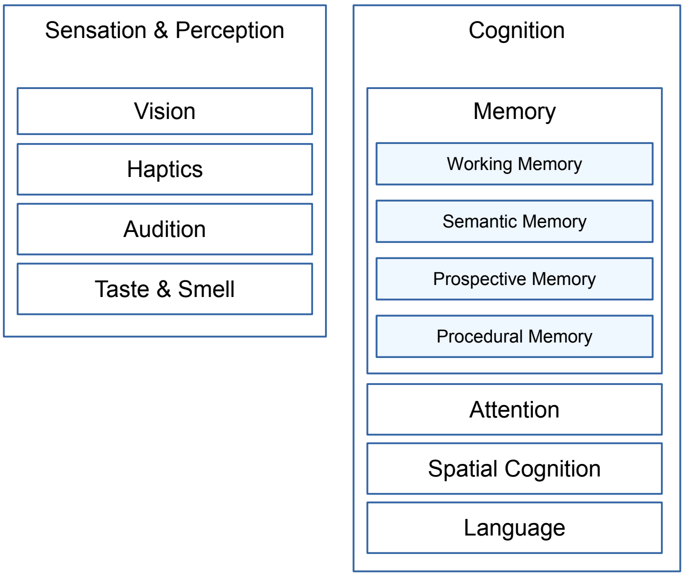

Figure 2.1: Overview of Age-Related Declines Categorized by Sensation & Perception, Cognition and Mobility.

2.2.1 Sensation and Perception

Recognizing an object or a thing in general requires the ability of sensing physical stimuli (e.g., hearing a noise) on the one hand and the interpretation of these signals on the other hand (e.g., identifying a noise as human voice) [Fisk et al., 2009]. With advancing age changes in sensory capability concerning vision, haptics, audition, taste and smell may occur. Although it is possible that the ability to distinguish different tastes and smells decreases, this is not of concern when using tablet-applications and therefore not described in detail within this work.

A very common impairment coming with age is the diminishing ability to focus objects at low distance (called *presbyopia*). Due to the stiffening of the lens in the eye, the lens is not able to adjust itself anymore in order to display a sharp image onto the retina. Additionally, when the lens becomes more yellow with advancing age, color discrimination for the short wavelength end of the spectrum (i.e., violet, blue and green shades) becomes more difficult. Hence, warm colors (like yellow or red shades) can be discerned more easily than cool ones. Next to visual impairments caused by the lens, the pupil affects the visual acuity as well. On the one hand, the pupil becomes smaller and therefore less light can enter the eye. Thus, the elderly require a higher illumination in order to see sharply. On the other hand, the process of dilating and contracting the pupil becomes slower, which is why adapting it to changes of illumination takes more time. As a result, the elderly are more sensitive to glare. Furthermore, the contrast sensitivity decreases. Age related changes in the neural circuitry of the retina and the brain cause a diminished capability to detect contrast. In addition, the visual field (i.e., the area wherein visual targets can be identified and discriminated without moving the eye or the head itself) narrows. Peripheral visual targets are therefore more likely missed by the elderly. [Farage et al., 2012, Fisk et al., 2009, Sardegna et al., 2002]

Concerning haptics, the elderly more commonly have problems in sensing and perceiving touches or pressure especially on the hands and feet. This causes more difficulties in recognizing when a contact is made to a surface or movable objects are changed in their position (e.g., pressing a hardware button). Moreover, impairments in vibration sensation make it difficult to sense high frequency vibrations (60 Hz and above), while sensing low frequencies is less affected. These declines in touch, pressure and vibration sensation can already become apparent within the fifties. [Farage et al., 2012, Fisk et al., 2009]

Similar to vibration signals, high frequency auditory signals (2000 Hz and above) are less perceptible for the elderly (in particular men) as well. This causes the effect, that words with high-pitched consonants (e.g., “ch”, “sh”) are harder to understand. Moreover, a higher sound intensity (i.e., volume) is needed by older people with hearing impairments (called *presbycusis*) from which already 60% of people aged 55 or above are affected. Often, for people above age 60 conversational speech is becoming harder to understand. Because the capability of distinguishing different concurrent sounds from each other and processing gaps between dynamic sound diminishes, speech recognition and discriminating speech from background noise is difficult for persons affected. [Farage et al., 2012]

2.2.2 Cognition

Cognitive functions such as memory, attention or spatial cognition are affected differently by age-related changes. The following descriptions of these cognitive functions are based on the literature from Fisk et al. [2009] and Farage et al. [2012].

As depicted in figure 2.1, four different areas concerning *Memory* exist: Working memory, semantic memory, prospective memory and procedural memory.

Working memory (also called "short-term memory") is the part of memory which temporarily keeps currently used information active and therefore accessible. The amount of information (i.e., the capacity of working memory) and the period of time it is accessible decreases with age.

Semantic memory (also called "long-term memory") refers to the capability of storing and remembering knowledge. Although the elderly need more time to access this knowledge, it is normally not getting lost with advancing age (as long as a person does not suffer from diseases like Alzheimer's).

Prospective memory is the ability to remember doing something in the future. It is differentiated between time-based (e.g., remembering to take a medication at a certain time) and event-based (e.g., remembering taking a medication when the alarm clock rings) memory. Time-based future actions are generally more often forgotten by the elderly than event-based ones.

Procedural memory describes the knowledge of how certain actions are carried out. This knowledge concerning well-known and practiced behaviors or activities (e.g., driving a car) remains intact. Acquiring completely new or minimally changed procedures is becoming harder to internalize for the elderly.

Besides memory, another cognitive function affected with advancing age is the *attention*. Focusing on a certain stimulus or event and processing its information requires attention and the ability to ignore competing stimuli. Since this ability declines with advancing age, switching attention between different sources of information is highly demanding for the elderly and processing these information takes more time.

Researchers showed a decline in *spatial cognition* as well. Locating objects within a three-dimensional space and developing a three-dimensional image in mind based on external cues becomes more difficult (e.g., mapping a two-dimensional coordinate on a map onto the three-dimensional space in the real world).

Moreover, there is a difference in understanding written and spoken language between older and younger people. Due to the minimized working memory capacity, processing and producing syntactically complex language is challenging especially for the elderly. When information is presented (written or spoken), drawing inferences (i.e., connecting this information) and understanding their intention is difficult for older people as well. Therefore, elderly people often have problems recognizing and understanding, for example, sarcasm or ironic expressions.

2.2.3 Mobility

With advancing age physical as well as psychological changes influence the way people are able to move and to control their movements. Due to the declining muscle strength and flexibility of the body, older people are more restricted in their range of body movements. Moreover, body movements become more error-prone, since perceptive abilities diminish (cf. section 2.2.1) and transferring signals from the brain to perform a movement becomes less precise. Compared to younger people, the elderly take more time in carrying out similar movements (on average 1,5 to 2 times longer). [Fisk et al., 2009, Farage et al., 2012]

2.3 Benefits of Touch Devices for the Elderly

Input devices in general can be divided into two categories: direct and indirect [Wood, 2005]. *Direct input devices* offer the possibility to directly interact with the desired object. Hence, touch devices like tablets are direct input devices, since a button for example can simply be touched to carry out an action. *Indirect input devices* translate a body movement into data which is required to interact with a system. A computer mouse, for example, is such an indirect input device. In order to click a button on the screen, the user has to move the mouse and click a hardware button on it. Therefore, the interaction with the system takes place indirectly by using the mouse.

Compared to direct input devices, indirect ones require more complex hand-eye coordination. To reach an intended point on the screen with a computer mouse, its movement using the hand has to be mapped onto the movement of the cursor on the screen. Additionally, different spacial information has to be processed as well. When the user moves the computer mouse towards him- or herself on the table, it moves downwards on the screen (i.e., spacial information from a three-dimensional space have to be mapped onto a two-dimensional display). Estimating and controlling the virtual distance the cursor is moved when the mouse is moved physically requires more attention and manual dexterity on the one hand. On the other hand, this way of interaction allows a very precise positioning of the cursor. Although indirect input devices are more efficient and accurate for experienced users, for novices these interaction methods can be more difficult to learn. Since the elderly show declines in movement control and spacial cognition (cf. section 2.2), moving a mouse and coordinating these motions can be more demanding for them. [Wood, 2005, McLaughlin et al., 2009]

By contrast, touch devices (i.e., direct input devices) require less hand-eye coordination, are more easy to learn and faster to use for people of all ages [Shneiderman, 1991]. These lower cognitive demands are especially beneficial for the elderly [McLaughlin et al., 2009]. But, it has to be considered as well that working with direct input devices causes arm fatigue more quickly and the hand may covers the screen and, therefore, interface elements may be not visible at first sight or are activated accidentally. Moreover, certain tasks or control elements which require high accuracy are not suitable for touch devices, since less precise inputs can be made. As an example, for modifying discrete values a slider control (requires precision) is more suitable for indirect input devices, while on direct devices simple “Up”- and “Down”-buttons are easier and faster to use [McLaughlin et al., 2009]. Thus, in order to make full use of the beneficial characteristics and compensate negative effects of touch devices, interfaces have to be designed taking these aspects into consideration.

In summary, with touch devices the elderly benefit from fast learnability, direct usage and less cognitive demands of touch devices. They offer novices the possibility to easily access device functionality and requires less training than indirect input devices. However, the sort of task, the interface design as well as the users experiences and capabilities, influence the suitability and effectiveness of touch devices.

2.4 Applications Used by the Elderly

Technology is in general less used by the elderly (older than 60 years) compared to younger people [Fisk et al., 2009]. This does not necessarily mean that older people generally wish to avoid new technologies. Fisk et al. [2009] showed that if older adults are conscious about the benefits of a certain technology, they also want to use it. Therefore, the most frequently used technologies concerning computer science are word processing programs, E-Mail and other communication programs as well as programs for information retrieval (i.e., browsers and search engines) [Morris et al., 2007]. There are also technologies which leave the elderly no other choice than to use them (e.g., a train ticket kiosk). As many older people feel frustrated in using them, this may be reasoned by the lack of age appropriate design [Fisk et al., 2009]. In fact, common reasons for the elderly for not using computers or the internet is thinking that it is not suitable for older people, too difficult or not useful [Morris et al., 2007]. Therefore, "the barrier is not age, but the respondents' idea that older people cannot or do not use computers" [Morris et al., 2007].

In order to develop applications for the elderly, an age appropriate design and making the applications benefits clear helps to gain a better understanding and acceptance. In this way, the application is seen as a supportive tool than as a useless obstacle an elderly is afraid to use.

3 Related Work

To design user interfaces in general many aspects have to be considered (e.g., the choice of colors, interactive design or navigation structure). Realizing such design aspects regarding tablet-applications for older people, common age-related changes have to be considered. Therefore, within this chapter guidelines are developed and discussed to provide a better understanding of these changes and how they can be compensated by design. In order to assign these guidelines to meaningful and logical groups regarding the corresponding design aspects, seven distinct categories are created and presented in this thesis: *Design* [DES], *Layout* [LAY], *Language and Wording* [LAN], *Icons, Graphics and Multimedia* [MMD], *Interaction* [INT], *User Support and Training* [SUP] and *Personalizing Application Interfaces* [PER]. For each category literature was collected and analyzed to identify findings, recommendations and principles that should be considered by developers to make tablet-applications more suitable for older adults. Furthermore, those age-related medical and psychological changes are discussed, which influence application design and why they are important to be considered. As a result, general, psychologically and medically justified guidelines are defined.

The literature analyzed in this thesis covers issues concerning web design for elderly users [Kurniawan and Zaphiris, 2005, Holt, 2000] as well as touch based interfaces in general [Loureiro and Rodrigues, 2014, Boustani, 2010, Caprani et al., 2012, Campbell, 2015]. Several papers cover more specific topics regarding special needs for older users like button sizes and spacing [Jin et al., 2007], interaction techniques and gestures [Stößel, 2012, Motti et al., 2013, Kobayashi et al., 2011, Mertens et al., 2010, Wacharamanotham et al., 2011, Lepicard and Vigouroux, 2012], user feedback [Tsai and Lee, 2009, Lee et al., 2009, Jacko et al., 2003] and data entry methods on touch devices [Nicolau and Jorge, 2012, Nischelwitzer et al., 2007, Chung et al., 2010]. These papers give a more precise insight in how the use of touch-applications can be facilitated for the elderly. A psychological view on how older people use interfaces in general and which physical impairments have to be considered is given by Fisk et al. [2009]. Though Loureiro and Rodrigues [2014] and Boustani [2010] already proposed design guidelines for touch screen interfaces for the elderly, these base on web design guidelines of Kurniawan and Zaphiris [2005] and do not discuss touch related topics (e.g., gestures and feedback) in detail. Moreover, the medical and psychological background of these guidelines is not reasoned sufficiently. This makes it more difficult for developers to recognize the intention of these guidelines as well as putting them into practice effectively.

The following section 3.1 covers issues of the category *Design*. Hence, requirements for style information like colors, appropriate color contrast and typography to support the elderly in their visual perception are discussed. However, such style information can be varied independently from values regarding the layout like font size, text layout, menu and information structure. The category *Layout* (cf. section 3.2) therefore provides a more detailed view on these topics. Issues concerning the use of language and wording are described in section 3.3. Since icons, graphics or multimedia content are often inevitable in tablet-applications, the guidelines discussed in section 3.4 propose how information can be supplied properly to older people. Moreover, touch applications provide a large variety of possibilities to interact with their content, however, not each way of interaction is suitable for older users. Therefore, section 3.5 presents a variety of suitable gestures as well as several types of user feedback and methods of entering data. The way elderly users should be supported in learning to use an application is discussed in section 3.6 (*User Support and Training*). Section 3.7 shows factors which may be customized by users to their personal needs and abilities. Finally, a brief summary of this chapter is given in section 3.8.

3.1 Design

The term “Design” can be defined and interpreted in many ways. In application development it could mean the concept and functionality of the back-end system (i.e., structure of program code) as well as the visual appearance of the front-end (i.e., the user interface). Because this work focuses on the development of user interfaces, here the general term “Design” does not cover the whole visual and interactive appearance of the application. In fact, this work differentiates aspects considering style information (e.g., color) from aspects like layout design (i.e., positioning and organizing elements – cf. section 3.2) and interaction design (cf. section 3.5). In this section the term “Design” covers how the choice of certain colors or typefaces can influence the visual perception of applications for older people. When interfaces are designed in consideration of age-related visual changes like in visual acuity or color perception, working with these interfaces can be facilitated for older users. Hence, readability and distinguishing certain information on screen can be enhanced when taking such age-related changes into account.

The following sections discuss and reason the selection of appropriate colors (cf. section 3.1.1), color contrasts (cf. section 3.1.2) and typefaces (cf. section 3.1.3) for interface design, which respect age-related changes in perceptual abilities.

3.1.1 Color

Colors can transport information or evoke certain moods and therefore can be widely used in interface design. However, age-related changes in color perception cause a reduced ability to discern colors especially in the short wavelength end of the spectrum (i.e., blue-tones). This is due to the diminished amount of incoming light reaching the receptors in the back of the eye (cf. section 2.2). Moreover, with increasing age the pupil is less able to dilate as widely as possible and the lens becomes yellowed [Fisk et al., 2009]. The latter absorbs and scatters parts of the blue light which makes it difficult to distinguish differences in short wavelength hues. Red and Yellow light can pass the lens unimpeded and objects appear with a warm, reddish glow [Sardegna et al., 2002]. Therefore, especially violet, blue and green tones become less noticeable and appear faded while bright, warm colors (i.e., yellow to red) are much easier to discriminate [Farage et al., 2012, Fisk et al., 2009].

This visual change is of great concern when colors in user interfaces are related to a certain information like grouping elements or signaling events (e.g., warnings). For decorative or plain display purposes of information the color contrast is more important than the explicit choice of warm colors. In other words, when the color carries no information it does not matter if the users finally perceives the intended color. Hence authors recommend choosing colors of the long-wavelength end and to avoid blue-tones for important information [Farage et al., 2012, Fisk et al., 2009, Campbell, 2015, Loureiro and Rodrigues, 2014]. This leads to the following guideline:

DES 1.1 Use colors of the long wavelength end of the spectrum if the color carries information – avoid blue especially.

Furthermore, using a large variety of colors in interfaces increases the need of constant refocusing. This tires the eye more quickly [Kurniawan and Zaphiris, 2005, Boustani, 2010]. This means:

DES 1.2 Colors should be used conservatively. Use colors to carry important and relevant information (e.g., warnings, grouping elements etc.)

Especially regarding the use of touch devices, Caprani et al. [2012] pointed out the problem of large dark or black colored areas in applications which highlight fingerprints and increase glare or reflections. An elderly eye is less able to recover quickly from glare or bright lights due to the smaller and less adaptive pupil and opaqued lens [Sardegna et al., 2002, page 6]. Therefore:

DES 1.3 Keep in mind that dark background colors increase glare and highlight fingerprints.

The choice of appropriate colors also plays an important role when displaying text. To increase readability Fisk et al. [2009] as well as Holt [2000] suggest to avoid colored (such as black text on blue background) and patterned background. On the one hand, this increases the contrast and therefore the ability to distinguish long text (cf. section 3.1.2). On the other hand it prevents text in the foreground to be distorted by a pattern in the background, even when the contrast of foreground and background is sufficient.

DES 1.4 Avoid colored and patterned backgrounds for text display areas.

When using colors, the color contrast is an important aspect to be considered as well. The higher the contrast between colors, the better these colors can be distinguished and perceived. This also influences older users when dealing with a tablet-application. The next section discusses this topic in more detail.

3.1.2 Contrast

With increasing age beside the diminished perception of certain colors, the contrast between two colors becomes less noticeable as well. The contrast sensitivity decreases when age-related changes in the neural circuitry of the retina and the brain occur which controls the ability to detect and recognize contrast [Sardegna et al., 2002]. This is especially important when text is displayed on screens or directly adjacent colors have to be distinguished. Hence authors recommend to keep color contrast high [Caprani et al., 2012] [Fisk et al., 2009]. For displaying text Fisk et al. [2009] and Farage et al. [2012] recommend to use black text on white background or vice versa, since the highest contrast possible is reached.

A more precise indication of how contrast ratio can be calculated and which values indicate a high, respectively a “good” color contrast are provided by the World Wide Web Consortium (W3C) [W3C, 2015]. The *Web Content Accessibility Guidelines (WCAG) 2.0* (presented by the W3C) cover several recommendations to make web content more accessible [W3C, 2008]. These guidelines contain a formula to calculate the contrast ratio of two colors, which can be found in Appendix A. In addition, it is suggested that “the visual presentation of text and images of text has a contrast ratio of at least 7:1” [W3C, 2008]. For large text (e.g., headlines) and text that is part of a logo or has pure decoration purpose a contrast ratio of at least 4,5:1 is recommended. These contrast ratio values also consider to avoid the combination of colors that can not be distinguished by color blind users (e.g., red and green or blue and yellow). Several online calculators indicating if two colors provide a proper color contrast use this formula provided by W3C [2008]. Because this Web Design related recommendation does not have to be adapted for touch interfaces, the following general guideline can be derived:

> **DES 2.1** To ensure legibility the color contrast ratio of text smaller than 18 pt should be at least 7:1 or 4,5:1 for large text or decorative text (following the formula provided by W3C [2008]).

3.1.3 Typeface

With increasing age the ability to sharply focus objects at low distance decreases (called *Presbyopia*) [Fisk et al., 2009]. Since older people tend to need more time reading text and instructions on screens [Chadwick-Dias et al., 2002] special requirements for displaying text on screens have to be considered in general. Using sans serif font types for text display on screens is known to be easier to read than serif font types [Holt, 2000] [Nischelwitzer et al., 2007]. Authors therefore recommend to use sans serif font types such as Arial or Verdana on computer screens [Holt, 2000] [Kurniawan and Zaphiris, 2005]. Nischelwitzer et al. [2007] found in their study, in which a mobile health application was designed and developed, that elderly users preferred the use of sans serif font types on mobile devices as well. For designing a tablet-application this means:

> **DES 3.1** Use sans serif font types (e.g., Verdana or Arial).

Holt [2000] cautions against using several font styles, since “italics make words appear wobbly, underlining makes them blur”, “condensed type squeezes letters together” and too bold font types are “too heavy to distinguish”. Decorative or fancy font types are generally not recommended for the elderly [Kurniawan and Zaphiris, 2005, Loureiro and Rodrigues, 2014, Fisk et al., 2009] and should be used for headings, if at all [Holt, 2000]. Furthermore, though uppercase text attracts attention, reading is slowed down compared to normal text. Hence, uppercase should be used sparsely like for highlighting key material [Fisk et al., 2009]. Each of these font variations cause difficulties in reading and therefore are not recommended for interface design for the elderly.

> **DES 3.2** Avoid decorative, italic, underlined and condensed font styles. Use bold font types and uppercase text only for highlighting key terms.

Another factor having significant impact on the readability of text is the size the text is displayed. This is covered in section 3.2.1. For choosing a proper text color see section 3.1.2.

3.2 Layout

Apart from the selection of appropriate style information like color or typeface (as already discussed in section 3.1), the question how content should be arranged and organized arises. This especially focuses on a better perception of content like buttons or text for elderly users.

Due to arising motor and visual impairments with increasing age (cf. section 2.2), reading text and reaching targets on touch screens can become more difficult. Such impairments are compensated by applying a sufficient size to touch targets and textual content, which altogether improves elderly users in using touch applications. Section 3.2.1 discusses in detail how the size of text and buttons is adjusted properly. Especially regarding textual content, besides an appropriate font size, an specific arrangement of the words within a text (e.g., amount of characters per line) additionally enhances the readability of paragraphs. Such improvements for layouting text are described in section 3.2.2. On the one hand, layout issues like size and textual arrangements affect how textual content can be read or buttons can be reached by elderly users. On the other hand, the mental processing of the entire content (within just one view as well as the complete application) can be enhanced as well. To ensure that the user can discriminate content within one single view (like searching for a specific information), in section 3.2.3 strategies for such an appropriate positioning of information are discussed. When views of applications change during user interactions, the users should be assisted in keeping track of elements and functions throughout the entire application. This is achieved through applying a consistent design as described in section 3.2.4. In addition, a menu structure which is clear and easy to use, facilitates navigating through the application. Guidelines for developing and presenting such a menu structure are presented in section 3.2.5.

3.2.1 Size and Spacing

Concerning older people, it is important to choose the size of some interface elements (e.g., buttons or texts) conscientiously. Authors often propose to provide large interface elements as well as more space between them to ensure that the information on the screen is perceived and distinguished entirely and correctly by elderly users [Kurniawan and Zaphiris, 2005, Loureiro and Rodrigues, 2014, Kobayashi et al., 2011, Caprani et al., 2012]. Though this is a very simple way to make an application “age friendly”, it can cause problems on small screens as less information can be displayed per view. Furthermore, the question arises how the term “large” should be quantified properly. In this section specific suggestions for button- and font-sizes are discussed as well as recommendations for proper spacing between buttons and within text.

It is generally known that older adults, compared to younger adults, take longer to make similar movements which also are less precise [Fisk et al., 2009]. The fact that older adults are more error-prone in movement control indicates that reaching a button on touch screens becomes more difficult with increasing age, especially if the target to hit is quite small. The most obvious way to compensate the diminished precision is to increase the size of interactive targets on touch screens. Moreover, larger targets can be detected more easily by users with impaired vision. In fact, it is generally accepted that elderly need more time and mental effort for performing a pointing task, when buttons are reduced in their size [Caprani et al., 2012].

Increasing the targets size hastily, frequently causes problems regarding the available space on small screens. This strategy moreover does not even increase the pointing accuracy of the elderly significantly. This has been shown by Jin et al. [2007] who determined the optimal size and spacing of buttons on touch screen interfaces. In fact, touching an isolated button (which has no adjacent buttons) on a touch screen was not considerably affected by manual dexterity. As a result, increasing the size of such isolated buttons has no measurable impact on pointing accuracy. Jin et al. [2007] propose a size of 11,43 mm square for such isolated buttons. When buttons are arranged in rows of adjacent buttons (e.g., on a keyboard), they are suggested to be slightly larger to ensure higher accuracy (16,51 to 19,05 mm square). In addition, the majority of the subjects in this study (26 older adults aged from 53 to 84 years) subjectively preferred button sizes of about 16,51 to 19,05 mm square, which were assessed to be “large, but not too large” [Jin et al., 2007]. Subjects with a high manual dexterity preferred relatively smaller buttons and less spacing between them. Additionally, they were more accurately and quickly in touching target buttons. For subjects with less manual dexterity vice versa. However, 11,43 mm square should be the minimum button size. The button sizes proposed by Jin et al. [2007] are illustrated in figure 3.1 and their usage is summarized in table 3.1.

Size	Usage
11,43^2 mm^2	Minimum size for separate/isolated buttons and when a slower reaction time of around 1400 ms is acceptable.
16,51^2 mm^2	For limited screen space and buttons used in rows of adjacent buttons.
19,05^2 mm^2	Recommended button size for faster response performance and higher accuracy. This button size is also the preferred one by the elderly users.

Table 3.1: Summary of the Button Sizes Recommended by Jin et al. [2007].

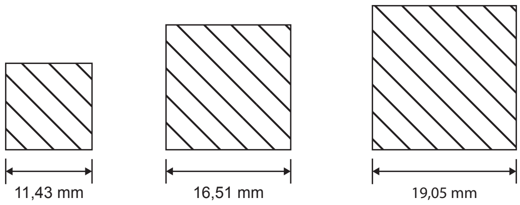

Figure 3.1: Illustration of the Button Sizes Suggested by Jin et al. [2007].

Hence, choosing a proper button size depends on the available space on the screen and the level of movement control of the user. Buttons do not need to be larger than 19,05 mm square. However, when they are smaller than 11,43 mm square they can not be accurately reached by the elderly any more. These recommendations were basis to establish the following general guideline:

> **LAY 1.1** Buttons, clickable icons and labels should range in size between 11,43 mm square minimum and 19,05 mm square maximum. Adjacent buttons used in rows (e.g., keypad) should be at least 16,51 mm square (cf. table 3.1).

The level of manual dexterity furthermore influences how accurate adjacent buttons, arranged in rows (e.g., software keyboards or keypads), can be handled. A proper amount of space between the buttons ensures that less errors through interaction (i.e., touching the wrong button) occur and less corrective inputs actions have to be made. Jin et al. [2007] therefore propose different spacing depending on the manual dexterity of the user. A button spacing of 3,17 to 6,35 mm (figure 3.2) is sufficient for people who are not affected by motor impairments. However, a button spacing of 6,35 mm to 12,7 mm leads to sufficient accuracy for users who suffer from such impairments. Spacing smaller than 3,17 mm or larger than 12,7 mm increases either the inaccuracy or the time needed for searching and finger movement. These recommendations of Jin et al. [2007] regarding button spacing are summarized in table 3.2 and lead to guideline LAY 1.2:

LAY 1.2 The spacing between adjacent buttons in a row should reach from 3,17 mm to 12,7 mm maximum (cf. table 3.2).

Spacing	Recommendation for Rows of Adjacent Buttons
0 mm	Not recommended. Does in fact not affect response speed, but shows lowest accuracy and preference ratings.
3,17 to 6,35 mm	Users with normal manual dexterity.
6,35 mm	Preferred by most subjects and showed highest accuracy.
6,35 to 12,7 mm	Users with poor manual dexterity.
12,7 to 19,05 mm and higher	Not recommended, because this will only increase the time for searching the screen and moving to touch the target button.

Table 3.2: Summary of Recommendations of Jin et al. [2007] Concerning Button Spacing.

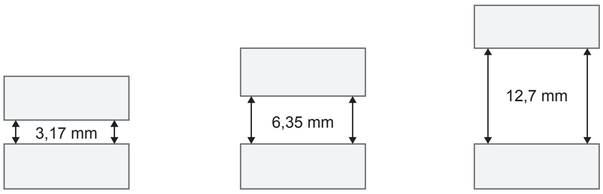

Figure 3.2: Illustration of the Button Spacing Suggested by Jin et al. [2007].

Reading characteristics of textual content is particularly influenced by the size of its characters (i.e., font size). On computer screens (unlike in print sector) the font size is generally measured in DTP-Point[1] (pt), whereby 1 pt matches approximately 0.3527 mm which is $\frac{1}{72}$ inch [Black, 1990].

Although several studies recommend to use a font size of 12 to 14 pt to accommodate elderly users, this recommendations are either made for large screens or print sector [Holt, 2000, Kurniawan and Zaphiris, 2005, Fisk et al., 2009]. Darroch et al. [2005] investigated the effect of varying font sizes between 2 and 16 points on reading text on small screens and compared the results of younger subjects to the ones of older subjects. On the one

[1]Unit of measurement for desktop publishing (DTP)

hand, reading very small text (i.e., font size 2-4 pt) unsurprisingly was found to be very discomforting for both older and younger users. On the other hand, when font size is too large (e.g., 14 to 16 pt depending on screen size) a single line contains less characters. This causes higher reading effort as every line break requires additional time searching for the corresponding start of the new line (cf. section 3.2.2). The older subjects preferred font sizes between 9 and 12 pt which were slightly larger than the ones preferred by the younger group (i.e., 9 to 11 pt). All in all, a larger font size does not result in a better readability.

In fact, choosing an appropriate font size depends on the screen size and resolution of the target device as well as on the visual acuity of the user. A font size of 9 pt can be read well by users with high or normal visual acuity and on small screens, while font size 14 pt suites best on large screens. Due to these dependencies, it can be helpful for the user when the application provides an opportunity to customize the font size (cf. section 3.7). Guideline LAY 1.3 summarizes this findings:

LAY 1.3 Font sizes for multiple lined text (i.e., primary text) should range between 9 pt and 14 pt and depend on screen size and the visual acuity of the user.

Line height (in typography called *leading*) is the amount of space between the baselines in successive lines of text within a paragraph. Single spacing defines a line height that is 20% larger than the font size of a paragraph [Bringhurst, 2012]. Holt [2000] and Boustani [2010] recommend a line spacing from 1.5-lines up to double spacing (cf. figure 3.3), due to the narrowing field of view (cf. section 3.2.3). Though it slows down the reader due to the increased moving distance for the eye between the lines, the text appears less compact and each line becomes better distinguishable from another. [Holt, 2000].

LAY 1.4 An 1.5 line spacing up to double spacing increases readability of text.

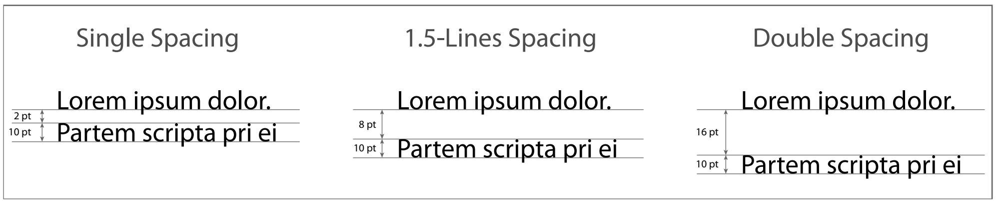

Figure 3.3: Comparison of Single, Double and 1.5-Lines Spacing.

Because changing just one of the two factors (i.e., font size and line spacing) influences the appearance of the entire text, they affect the reading characteristics of text in a major way. However, the legibility of text does not depend on the font size and line spacing alone. Other layout issues like the amount of characters per line or text justification (as mentioned previously) have to be taken into account as well. These topics are discussed in section 3.2.2 in more detail.

3.2.2 Text Layout

Another factor which influences the reading characteristics of a text is the amount of characters per line. In print and web-design it is a common recommendation to display 60-75 characters per line [Bringhurst, 2012]. The number of characters fitting into a single line are determined by the size of the target display in combination with the font size (as mentioned in section 3.2.1).

> **LAY 2.1** Keep text lines short in length: The amount of characters per line for primary text should range between 60 and 75.

When the font size of a paragraph is increased and thus the screen size is no longer sufficient to display the entire text at once, content often becomes scrollable. In fact, such a scrollable text mostly causes more problems for the elderly than reading a text with a slightly smaller font size [Nischelwitzer et al., 2007]. Thus, longer paragraphs should be either displayed more compact by decreasing font size slightly or it should be considered to divide it into several pages to avoid text-scrolling. Thus, the following guideline is defined:

> **LAY 2.2** Avoid the need of scrolling to read a text. Rather consider to decrease the font size or line spacing.

The problems which occur for elderly users when content in general (i.e., not solely text) is scrollable are discussed in section 3.5 in more detail. Just like scrolling, moving text of any type (e.g., horizontally or vertically) impairs its readability as well. Such movements (e.g., automatic scrolling text) are difficult to process and cause confusion especially for elderly users [Fisk et al., 2009, Kurniawan and Zaphiris, 2005]. Thus, text should always be displayed static.

LAY 2.3 Avoid moving text like automatic scrolling.

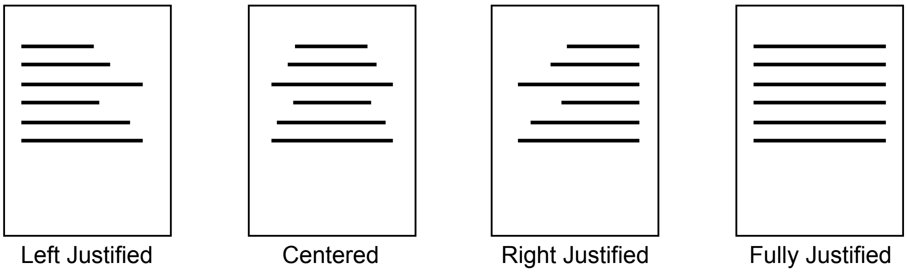

Figure 3.4: Types of Text Justification.

The justification of text indicates the way the words are placed within a line. Text can be left, right, fully justified or centered (cf. figure 3.4). Centered text can be used for headings but should not be used for longer paragraphs. Reading fully justified text (i.e., the words are spread equally over the lines) can be uncomfortable, due to the large variation of space between the words. To ensure that text is displayed in a readable way and in a familiar layout, left justified text should be used. [Holt, 2000, Kurniawan and Zaphiris, 2005]

LAY 2.4 Multiple line text should be left justified.

Paragraphs and topics are often indicated by headlines and thus need to be apparent and distinguishable. When they are at least 6 pt larger than the primary text, headings can be discerned better [Holt, 2000]. Designers, therefore, should consider the following guideline:

LAY 2.5 Provide clear and large headings.

3.2.3 Content Structure

Another issue concerning the layout of an application is the question about which content or information should be displayed where and in which way. Possible visual impairments can influence the perception of content on the screen as well as an age-related decline of attention and working memory (cf. section 2.2).

The diminished ability to perceive colors and presbyopia were discussed in section 3.1.1 and section 3.1.3. Another factor which is often impaired with increasing age is the narrowing field of view. This describes the area wherein visual targets can be perceived and discriminated from the environment without moving the eye. With increasing age this field of view impairs and especially distinguishing peripheral visual targets becomes more difficult. Hence, to process their environment older adults need a higher degree of attentiveness and thoroughness. [Farage et al., 2012]

When designing applications for the elderly, scanning a screen for certain content should be facilitated as well as recognizing any displayed information. This can be reached by aligning key information in the central visual field and when it can be discriminated easily [Farage et al., 2012, Kurniawan and Zaphiris, 2005]. In addition, the importance of information can be highlighted (and therefore recognized better) by a specific emphasizing design (e.g., different color or size) or by displaying it isolated from other content to catch the users attention.

Attention, which can be described as "the capacity to maintain focus on a particular stimulus" [Farage et al., 2012], is affected by changes with age as well (cf. section 2.2). Older adults increasingly have difficulties in moving their attention from one thing to another and are also less able to ignore competing information [Farage et al., 2012]. This especially makes it difficult for elderly to visually search for things. Such searching tasks in applications (e.g., "Where can I find the *home*-button?") can be enhanced by simply reducing the total amount of simultaneously displayed information. A minimum of non-relevant information keeps the content layout simple and "tidy" on the one hand, on the other hand elderly users can focus on the content they are looking for and are not distracted by rapid motion [Farage et al., 2012, Kurniawan and Zaphiris, 2005]. Tullis [2007] found that the older adults in their study tend to read more text (on web sites) even when it was not relevant for completing a task. Especially avoiding irrelevant text on screens can help the user to focus on their intended task or goal or to find certain information.

That is, when designing an application, the narrowing peripheral vision and changed attention in older age can be compensated by considering the following guideline:

> **LAY 3.1** Simplicity of visual perception is key: Avoid visual clutter, distracting visual stimuli and non-relevant information due to the declining visual field.

Furthermore, the decline of working memory capacity with increasing age (cf. section 2.2) is of great concern regarding the layout of information as well. Working memory (also called short-term memory) includes information that has recently been obtained and which is currently used in mind. Our working memory is neither able to memorize a large amount of information nor to memorize it for a long time [Fisk et al., 2009]. Both factors decrease with age [Farage et al., 2012]. While the working memory capacity of young adults covers about 7 chunks of information [Farage et al., 2012], only 5 chunks or less can be processed by the elderly [Nischelwitzer et al., 2007]. This limitation can be compensated by organizing information within groups of around 5 information blocks which in turn can be arranged with additional (but in total about 5 per superior information group) distinct information groups. When the attentional focus stays within one of the information groups, only the chunks within this group have to be processed. In brief, this means:

> **LAY 3.2** Minimize working memory demands: Keep the number of information blocks presented or processed at once limited to around 5.

Through these guidelines the positioning of elements within the same view can be optimized. Since applications do commonly consist of several views, it is important that the user recognizes similar elements and functions throughout the entire application. Keeping this in mind the application should be consistent in design and functionality. The term consistency, its importance and how it can be realized are pointed out in the following section 3.2.4.

3.2.4 Consistency

In user interface design the term *consistency* and its importance was coined by Ben Shneiderman [Shneiderman and Plaisant, 2005] and Jakob Nielsen [Nielsen, 1995] who established general rules and heuristics for enhancing usability of user interfaces. A consistent design refers to each interface element and interaction method within the application. This includes the positioning and design (e.g., regarding typography or colors) of elements (e.g., of warnings or buttons), the terms that are used, the actions that are caused by similar interactions as well as the interaction sequences for reaching a similar goal. Each element (e.g., a button or an icon) and interaction (e.g., clicking a button to open a menu) should stay the same throughout the application, so the user is able recognize similar elements and functions better. Furthermore, involving actions or conventions, that are learned and established within other systems (e.g., using "OK" and "Cancel" buttons in dialogs) or the real world (e.g., using traffic signs), can help to elaborate a consistent application [Shneiderman and Plaisant, 2005]. A consistent design assists the user in relying on previously learned procedures and conventions. Thus, the result of interactions are more predictable which facilitates using an application.

Within applications for elderly users, consistency plays an even greater role. Every application requires a certain amount of training to memorize how it is organized and actions are performed. This knowledge about how to perform previously learned activities and procedures is called *Procedural Memory* (cf. section 2.2) [Fisk et al., 2009]. Though older adults have more difficulties in learning new procedures, the knowledge of already internalized activities (e.g., the knowledge how to multiply two numbers) stays intact and is easier to access than to inhibit [Fisk et al., 2009]. Through a consistent design less new processes or actions have to be learned whereby procedural memory is supported. This is reached by not suppressing already internalized knowledge about performing certain actions. This knowledge can be used to accomplish similar procedures within other systems. For example, if an user of a regular PC has learned to close a window or dialog with a button in the upper right corner, dialogs in tablet applications should not be closed with a button in the upper left corner.

In addition, older people tend to rely more on external cues to gain information from memory, and ,therefore, suffer more mental effort than younger when expectations (i.e., learned processes) are not met by consistent design [Fisk et al., 2009]. The mental process that is linked to this cue could not meet the users expectation (which he/she learned previously) and therefore cause confusion. Guideline LAY 4.1 summarizes these findings:

> **LAY 4.1** Consistent design is even more important for the elderly than it is for younger people. Therefore, the location of elements and functions should remain the same across views and similar functions should act the same way throughout the application.

The less mental effort it costs a user to understand the application, the higher the acceptance to use it. Due to the strong correlation between consistent design and mental effort for the elderly, consistency is highly significant for the design process. However, understanding an application also depends on the internal organization of the content and the quality of the menu structure to reach it. Guidelines for developing such menu structures are proposed in the following section 3.2.5.

3.2.5 Navigation and Menu Structure

An application always grants the user access to a specific set of information. To control and oversee this information, an underlying internal structure is required to present the information in a simple way. This internal structure is displayed to the user through a menu, an interface element with which functions and views are accessible. The design and structure of a menu affects the users understanding of his interactions and the possibilities of the application. Thus, it influences the way he/she navigates through the application and interacts with it.

Especially elderly users can be supported by providing an appropriate menu structure with well-considered menu items. Tullis [2007] found that elderly users spend more time comparing and contrasting menu items to which would suite their intended action best. When such menu items are grouped into categories with labels which are unambiguously and whose differences are apparent, navigating and interacting with the application can be simplified. For a better distinction of certain menu groups (e.g., main menu and secondary menu) Caprani et al. [2012] suggest to differentiate these by their shape and style additionally. This results in:

> **LAY 5.1** Group information and actions into meaningful and clearly worded categories. The difference between the items should be apparent.

Beside the grouping and labeling of menu items, it is also important to be able to identify the existing navigation menus as such. Navigation cues (e.g., breadcrumbs [2], “next”- and “previous”-buttons, menu bars) help the user to find a route through the application and/or show the current location within the application. By displaying such cues clearly visible especially elderly are supported in managing and navigating through the application [Kurniawan and Zaphiris, 2005].

[2] “Breadcrumbs show each level of hierarchy leading to the current page, from the top of the application all the way down. In a sense, they show a single linear »slice« of the overall map of the site or app” [Tidwell, 2010]

An additional important issue regarding navigation cues is to keep them consistent in design as well as in behavior (cf. section 3.2.4) [Farage et al., 2012]. When the current view of an application changes, previously used navigation cues should stay at the same position and have the same function as the user has learned before.

The following two guidelines LAY 5.2 and LAY 5.3 summarize these findings:

> **LAY 5.2** Provide a clear and consistent navigation by displaying precise navigation cues and actions that are readily visible and accessible.

> **LAY 5.3** The current location in the application should be obvious to the user all the time.

Menu structures can be organized in broad or deep hierarchies (cf. figure 3.5). In broad hierarchies more nodes are allocated per level than in deep hierarchies. Hence, one level of a broad menu structure can contain a large amount of nodes, where a node of such hierarchies corresponds to a menu option. If the same overall amount of menu options are distributed on more levels with less options per level, it is called a deep hierarchy. As an example, the menu structures showed in figure 3.5 both contain 14 nodes whereas these are distributed on five levels in the deep hierarchy on the left and on three levels in the broad hierarchy on the right. Information in a deep hierarchy on the one hand can be organized more clearly due to the increasing number of subcategories. Because the labeling of each subcategory delivers more information about its content, the description of the content itself becomes more precise. On the other hand, with more subcategories more decisions need to be made to reach the desired information. Therefore, it can be more difficult for the user to find a route through such deep hierarchies . Especially older adults more frequently need to head back to the previous level or have problems of loosing orientation in such deep hierarchy structures [Fisk et al., 2009]. This causes a high demand on working memory which is also known to decline within age (cf. section 3.2.3). In other words:

> **LAY 5.4** Avoid deep hierarchies in menu structures hence the user does not get lost in the application.

The amount of interim steps which have to be made to reach a certain goal also affects the success of the user. To achieve such a goal, actions and commands are selected

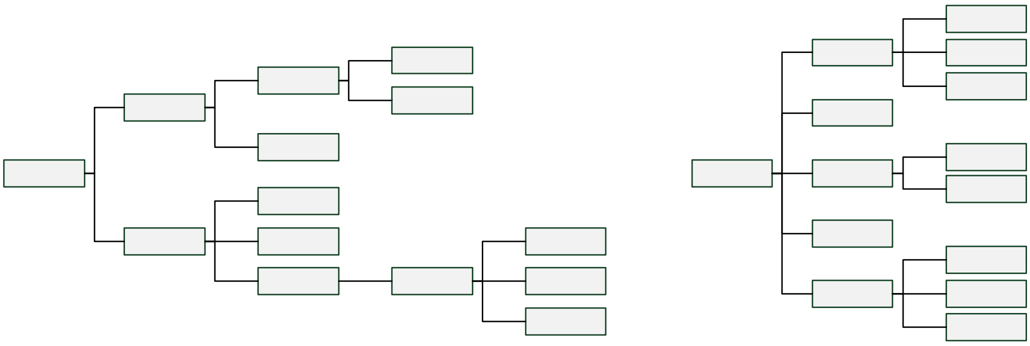

Figure 3.5: Types of Menu Structures: Deep Hierarchy (Left), Broad Hierarchy (Right).

sequentially by the user (i.e., step by step). If anywhere in this sequence an error occurs (e.g., touching the wrong button), the user may looses orientation and has to start over again. The probability of success increases when the number of steps in the procedure decreases. Because in most cases the number of steps can not be reduced to only a single one (not only due to the lack of space), a trade-off between the number of steps in the procedure and the number of control elements (i.e., buttons) has to be made. Especially for older adults this is important because “when it comes to tasks with significant memory demands, older adults are more likely than younger ones to commit errors in reproducing a long sequence. Hence, minimizing the number of steps in a procedure can be particularly helpful to older users.” [Fisk et al., 2009].

Furthermore, through minimizing the number of steps to accomplish a task, the load of procedural memory as well as working memory (cf. section 2.2) is decreased. When less steps (no matter if they are already accomplished or still remaining) have to be kept in mind, less errors occur while performing the entire sequence of steps. This leads to following guidelines:

LAY 5.5 Minimize the number of steps to complete a task as well as the number of control-elements to increase the probability of successfully completing the task.

LAY 5.6 “Don’t force the user to keep information in mind for too long to accomplish a single task.” [Fisk et al., 2009]

In summary, layout issues in application design cover a wide field. Choosing a proper size of content elements is as important as structuring the information logically, simply and consistently.

3.3 Language and Wording

Using a proper language in applications influences the way elderly users interact with them. Studies in the field of web design showed that older people tend to be more cautious in clicking on links or buttons, since it is not always clear to them what action will be caused [Chadwick-Dias et al., 2002, Tullis, 2007, Nielsen, 2013]. By labeling interactive elements using the active voice (e.g., “Save Password” instead of “OK”), the consequences which follow on an action can be made more clearly and foreseeable to the user.

Furthermore, the elderly tend to feel uncomfortable in trying new things [Nielsen, 2013]. A positive phrasing (e.g., “You have successfully saved your password.”) confirms the user in using the application more confidently. Such positive phrasing is also important regarding error messages. Since the elderly were found to be “twice as likely to give up on a task” than younger adults [Nielsen, 2013], it is important to reinforce the intention of the user when an error occurs. Formulating such error messages positively can motivate the user to try again. Guideline LAN 1.1 therefore is:

> **LAN 1.1** Language should be simple and clear. In addition, it should use active voicing and positive phrasing.

Older adults tend to have more problems comprehending language when connections between concepts have to be made, which are not explicitly shown [Fisk et al., 2009]. Textual cues (e.g., labels) support the user to understand and recognize the current state of the application and define every possible change of state precisely. This state information is indicated more clearly, when such textual cues are expressed with familiar terms. Hence, the use of an application can be facilitated when ambiguous terms are avoided and less inferences have to be made by the user.

In particular, terminology which is very familiar and obvious among application developers like “Touch”, is not always well known to elderly users, particularly for non-native English speakers [Nischelwitzer et al., 2007]. However, technical terms can not be avoided in every application (e.g., healthcare applications). This can be compensated by providing a glossary [Holt, 2000]. Furthermore, Campbell [2015] reminds developers to consider if phrasing assumes that the user is at a certain stage of life or certain age.

These findings are summarized in guideline LAN 1.2:

> **LAN 1.2** Phrasing assuming prior knowledge (e.g., technical terms) or a certain (especially young) age of the user should be avoided. Provide a glossary if technical terms are necessary.

In summary, when developing applications for the elderly, language is the key to make an application more accessible. It offers the opportunity for older users to understand applications and to use them more confident.

3.4 Icons, Graphics and Multimedia

Icons or graphics convey information about functionality without using words. When the meaning of an icon or symbol is familiar to the user (e.g., a house leads to the “Home”-view) the intended context can be recognized quickly, possibly more quickly than through reading a text message or label [Fisk et al., 2009]. To make sure if the intended meaning is also understood properly, Farage et al. [2012] propose to test these icons with elderly people. This possibility of supplying information without the need of text leads to the following guideline:

> **MMD 1** Well designed or familiar symbols and icons can be more effective ways to convey information than text messages.

This guideline, however, also includes that not each control element needs to be accompanied with an icon or graphic. This is only useful in cases when a pictorial representation leads to better and faster understanding than a textual message would do. Vice versa, adding a label or text message to icons will help to avoid misunderstanding the underlying action or compensates diminished visual capacity. [Holt, 2000]

> **MMD 2** Where possible provide a label or text for icons or illustrated instructions.

Multimedia content describes information that relies on the parallel output of different content forms like visual and auditory information. If verbal information is offered, it must be considered that with increasing age auditory as well as visual perception impairs (cf. section 2.2). The frequency spectrum which can be perceived diminishes with age especially within the high frequencies above 4000 Hz, while low frequencies below 1000 Hz are not affected significantly. To understand speech without loss, the higher frequency bands are inevitable. Especially the hearing of consonants is the most problematic issue here. The sound energy of consonants is mostly concentrated in frequencies above 8000 Hz (e.g., “ch”, “sh”, “z”) and leads to a higher probability of misunderstanding words for the elderly. Since women and children tend to have higher pitched voices than men, it can be more difficult to understand female voices for the elderly and should therefore not be used to convey verbal information. A slower speech rate furthermore supports older people in processing this information. [Fisk et al., 2009, Farage et al., 2012]

> **MMD 3** “Speech rate of verbal information should be kept to 140 words per minute or less, male voices should be preferred to female voices and synthesized speech should be as natural as possible.” [Fisk et al., 2009]

Since older people with hearing losses have to rely more on the interpretation of the context to understand speech, it is important to provide a good structured content. This assists users to guess words they did not understand acoustically from the context. It can be helpful to reinforce important grammatical subdivisions of sentences (i.e., full stop or comma) by pausing to provide ample time for processing the information heard [Fisk et al., 2009]. In addition, providing subtitles to verbal information ensures that the information is actually perceived by elderly people with hearing impairments. By contrast, users who suffer from visual impairments benefit from a spoken text presentation. This means:

> **MMD 4** “Consider providing parallel visual and auditory presentation of language” (i.e., subtitles or a text-to-speech function) [Fisk et al., 2009].

Furthermore, speech perception is less error-prone if further auditory signals like background noises or music are reduced. Such interfering signals can mask primary sounds (i.e., speech) which therefore are harder to distinguish. Elderly people tend to be more susceptible to such masking of sound frequencies by noise [Fisk et al., 2009], which leads to following guideline:

> **MMD 5** “Limit your sounds to one at a time; for example, speech over music may be hard to distinguish.” [Holt, 2000]

Another issue which is affected by the diminishing auditory perception with increasing age is the choice of appropriate auditory feedback. This is discussed in detail in section 3.5.3.

3.5 Interaction

The previous sections 3.1 and 3.2 focused on the choice, arrangement and presentation of interface elements. This section describes interaction possibilities with these elements which are a crucial factor influencing the usability of touch applications. In fact, there is a huge variety in providing interactive methods for the user to attain or entering certain information. Though many different types of interaction methods are established and well known, the question rises if these are also suitable for older users. This section covers whether and in which way interacting with touch applications changes within age and how these changes should be considered in interaction design. Since touch devices deliver a large variety of developing and using gestures, section 3.5.1 discusses which gesture types should be preferred for elderly users. Moreover, entering data like text or numbers is essential when user input is processed by an application. Section 3.5.2 covers techniques and best practices to provide suitable input methods for older users. Finally, each action of the user should cause a response to inform the user about success or failure of the action. An appropriate feedback for elderly users takes perceptual changes in consideration and is pointed out in section 3.5.3.

3.5.1 Gestures

Since Apples iPhone was introduced in 2009, several interactive gestures for multi-touch devices became commonly known by users and associated with certain actions. However, nowadays similar gestures for certain actions are used by devices with other operating systems like Android or Windows as well. Figure 3.6 provides an overview of those core gestures which are provided in each of these operating systems.

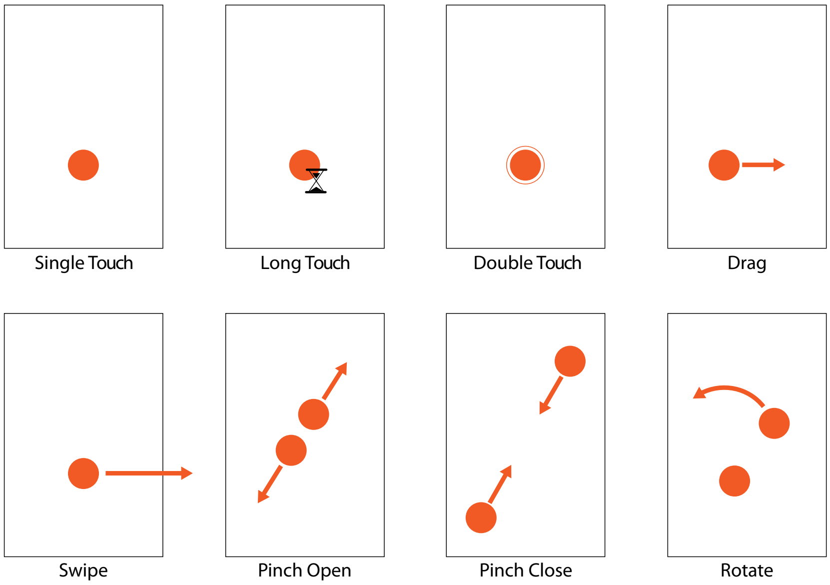

Figure 3.6: Illustration of Common Gestures on Touch Devices.

Although the same gesture patterns are used by iOS as well as Android and Windows as well, the functionality between the systems differs. To give a brief overview, table 3.3 compares the presented gestures with their associated system related functions. Some of these gestures are combined with the same functionality independently from the operating system. For example, the *Double Touch* or *Pinch Open* gesture is used to zoom into content by each of these operating systems. However, others cause different system related actions like the *Long Touch* gesture.

In addition, figure 3.6 shows that these core gestures only consist of a few different interaction patterns (simple touches and strokes) although a large variety of gestures are possible. The

Gesture	iOS	Android	Windows
Single Touch	Selecting an item or triggering a functionality		
Long Touch	Displaying a magnified view for cursor pointing	Selecting multiple items and interacting with them via a displayed contextual action bar	Opening a context menu
Double Touch	Zooming into content		
Drag	Scrolling content or dragging an element	Moving between views and for precise scrolling content within one screen	
Swipe	Scrolling content quickly or moving between screens		
Pinch Open	Zooming into content		
Pinch Close	Zooming out of content		

Table 3.3: Comparison of Standard Gestures Used by Android, iOS and Windows Operating Systems [Apple Inc., 2014, Android Open Source Project, 2015a, Microsoft Corporation, 2015].

question arises whether these common gestures are suitable for older users or whether other more meaningful gestures should be provided.

Of course, the interaction patterns listed in figure 3.6 and table 3.3 do not cover all possible and especially practical gesture interactions at all. A gesture may consist of a single touch up to several strokes including one or more fingers or even hands. The complexity to perform and recognize a certain gesture mainly decides whether it is suitable for a certain use case. For example, drawing the letter “O” on the screen to open a certain file is easy to handle. However, it can be recognized by the application either as the letter “O”, a zero or encircling an object and therefore may leads to misinterpretation. It is possible that gestures which are well known and easy to perform by younger people, may be judged by older users as hard to execute or not suitable for a specific tasks.

To analyze whether a gesture is practical and suitable for older users, a classification of all gestures is required considering the infinite number of possible gestures. Therefore, Stößel [2012] collected 568 different gestures and analyzed how many fingers, number of segments (a continuous movement of the finger without lifting it off) and number of strokes (movement of the finger from one resting point on the surface to another) were needed for its execution. As a result Stößel [2012] provides following gesture classification:

Indexical gestures The gesture consists of a mere positioning of the finger on a certain screen object or region. A simple tap is the predominant indexical gesture.

Manipulative gestures Screen objects or regions are manipulated with the help of movement patterns such as repeated tapping, long presses, dragging movements, swift swipe or flick movements, spreading or pinching movements, encircling or boxing screen objects etc.

Alphanumeric gestures These gestures consisted of one or more letters or numbers which were drawn with the finger on the screen. In few cases, even whole words were drawn.

Iconic gestures Drawings that result in the depiction of real world objects. Common iconic gestures were arrows, but also crosses, houses, magnifying glass, ear, loudspeaker, houses, scissors and other objects were schematically drawn on the screen.

Symbolic gestures A sign that was neither an iconic object depiction, nor an alphanumeric character, which counted as an extra subset category. Examples comprise e.g. a minus sign, plus sign, bracket, question mark etc.

Combined When a gesture consisted of separate parts which stem from different categories, they were counted as combined. In most cases, these gestures contained a manipulative and an iconic or symbolic segment.

Definition by Stößel [2012]

There are two factors which mainly decide whether a gesture is suitable for older people or not. On the one hand, this is the complexity of a gesture structure, on the other hand, the process of memorizing and finding the gestures and the action it causes. The latter is important to consider when cognitive changes occur with age. Forgetting the functionality behind a gesture is more frequently the cause of an error than insufficient manual dexterity to perform the gesture [Stößel, 2012]. Also the lack of visual clues for typical functions (e.g., zooming through a *Pinch* gesture – cf. figure 3.6) affects that gestures are unknown to the user [Kobayashi et al., 2011]. By providing such clues, adequate instructions and training opportunities, older adults may remember and perform gestures better. Thus:

> **INT 1.1** Instructions, training opportunities and clear visual clues facilitate memorizing and familiarizing gestural actions.

In addition, due to age-related impairments in movement control (cf. section 3.2.1) it is recommended to keep movement tasks in general simple and discrete rather than complex [Farage et al., 2012]. Therefore, because of their simplicity, *Indexical* and *Manipulative* gestures are frequently recommended and overall rated to be more suitable than symbolic or iconic gestures [Stößel, 2012, Loureiro and Rodrigues, 2014, Motti et al., 2013]. Besides, the more of such simple gestures are used, the less different gesture patterns have to be memorized and the less time is needed for remembering and executing gestures as well as completing tasks. For this reason the following guideline implies:

> **INT 1.2** "Prefer indexical and manipulative gestures over symbolic and iconic gestures" (following the gesture categorization by Stößel [2012]).

Even though *Iconic* and *Symbolic* gestures are more complex to perform, Stößel and Blessing [2010] found that elderly users more likely accept such gestures than younger adults. In addition, more difficult gestures are indeed performed slower but not less accurate by the elderly compared to younger adults [Stößel, 2012]. Hence, it is not generally necessary to avoid complex gesture interactions, but more complex ones can be handled by older adults effectively as well [Stößel et al., 2010, Motti et al., 2013]. The higher acceptance of these more complex gestures by older people can be explained with the similarity of these gestures to real world signs and objects. This familiarity is significantly more important to older users compared to younger ones [Stößel, 2012]. For example, drawing a check mark to confirm an action is indeed less efficient than pressing an "OK" button, but might be rated more suitable for certain use cases by elderly users. Stößel [2012] therefore provides following guideline:

INT 1.3 “Favor familiarity of a gesture pattern over its execution efficiency” [Stößel, 2012]

Alphanumeric gestures, however, are in general not recommended by Stößel [2012]. For older people it is difficult to “make the association between the [...] letter and the connected command”. Sufficient repetition and training is needed to internalize such gestures and thus are more practical as shortcuts for experienced users than for novices. This means:

INT 1.4 “Avoid alphanumerical gestures.” [Stößel, 2012]

Although indexical and manipulative gestures are the easiest ones to perform, understand and remember, this does not mean that more complex gestures should be avoided in general. In fact, manipulative gestures exist which seem easy to perform on the first sight (based on the required number of fingers, segments and strokes) but actually are not suitable for older users. Studies have shown that especially scrolling (through dragging the content), drag and drop and double touch operations cause difficulties for older users [Nischelwitzer et al., 2007, Kurniawan and Zaphiris, 2005, Caprani et al., 2012, Wacharamanotham et al., 2011, Findlater et al., 2013, Al-Razgan et al., 2012].

The problem regarding scrollable or automatic scrolling text was mentioned already in section 3.2.2. One issue is the loss of the current line and thus the orientation within the text [Nischelwitzer et al., 2007]. As scrolling operation on touch screens mainly consist of dragging the content up- or downwards, it is necessary that during this action the finger does not loose contact to the surface. On resistive touch screens constant pressure is needed additionally. Especially for people with age-related impaired manual dexterity or imprecision (e.g., caused by a tremor) this is problematic [Leonardi et al., 2010, Wacharamanotham et al., 2011]. Such scrolling operations are avoided by dividing content into several views which can be accessed through swiping or pagination controls (e.g., “Next” or “Previous”-buttons) [Caprani et al., 2012, Dahn et al., 2014].

Another important issue regarding scrolling operations is reported by Stößel [2012]. For example, performing a dragging gesture downwards to scroll, could be either interpreted as dragging the content downwards (i.e., scrolling upwards) or as dragging the window frame downwards (i.e., scrolling downwards). This affects confusion depending on prior experiences or metaphors the user associates with the corresponding gesture. Thus, the following guideline cautions against using scrolling. Alternative methods should be used instead.

> **INT 1.5** Turning over pages (like through "Next"- and "Previous"-buttons or swiping) should be preferred to scrolling up or down.

Similar to scrolling operations, drag and drop operations are difficult to handle for older people as well. With advancing age performing drag operations by constantly touching the surface becomes more difficult. Drag operations are therefore very demanding for older people and have to be repeated several times until they are internalized [Leonardi et al., 2010]. Thus, authors caution against using drag and drop operations [Findlater et al., 2013, Al-Razgan et al., 2012, Murata and Iwase, 2005]. For the same reason, it is also possible that the *Long Touch* gesture (cf. figure 3.6) becomes difficult to perform as well, though this has to be further investigated. In fact, a *Long Touch* gesture is hard to separate from a *Double Touch* if the user is trembling. This can also be of concern, when buttons are at the same position on two successive views. The button on the successive view may be activated unintentionally, when these views change too fast. In order to prevent such erroneous inputs, *Double Touch* gestures should be avoided [Caprani et al., 2012]. These findings are briefly summarized in the following guideline:

> **INT 1.6** Avoid drag and drop operations and double touch gestures.

If double touch gestures are inevitable, the movement speed of the elderly needs to be considered as well. In general, elderly users tend to be 1.3 to 2 times slower compared to younger adults when performing similar movements, [Fisk et al., 2009, Stößel, 2012]. Thus, Stößel [2012] proposes the following guideline for time-based gestural interactions:

> **INT 1.7** "Accommodate for slower gesture execution for time-critical events (e.g. multitap latencies). Movement is slowed by 1.3 compared with younger users." [Stößel, 2012]

Other gesture types which have been investigated by Stößel [2012] are curved gestures, for example a rotation gesture (cf. figure 3.6). Such gestures are reported to be "particularly difficult" by the older users. Thus:

> **INT 1.8** "Employ curved gestures sparsely." [Stößel, 2012]

Besides Stößels categorization listed above, touch interactions can be differentiated by the number of contact areas which are needed to carry out the gesture. While single touch interactions require just one finger (e.g., *Touch* or *Swipe*), multi-touch interactions are performed by using at least two fingers of one or both hands (e.g., *Pinch Open*).

The question arises whether there is a difference between younger and older adults in performing and subjectively rating single- and multi-touch gestures. In fact, Stößel [2012] investigated, single-touch gestures are indeed preferred by older adults over multi-touch gestures and additionally are performed less accurate. On the one hand, the size of the hidden surface through the hand is larger when two or more fingers are used. Hence, more concentration effort is needed to visualize the missing parts additionally to the visible surface. On the other hand, performing multi-touch gestures requires more manual dexterity than single-touch gestures, so older adults are rather affected by fatigue. [Lepicard and Vigouroux, 2012]

INT 1.9 Multi-touch gestures are not recommended for older users.

Comparing the findings of this section with the gestures illustrated in figure 3.6, one can say that some of these commonly used gestures are not suitable for older users. Especially the zoom operations (i.e., *Double Touch* and *Pinch Open/Close*) may be difficult to handle, since these gestures are not executable accurately with motor impairments like a tremor. In addition, gestures containing stroke movements (e.g., *Drag*, *Swipe* or *Rotate*) should be avoided for the same reason. Since simplicity in executing gestures is as important for older people as memorizing them, not just the *Single Touch* gesture, but also iconic or symbolic gestures are suitable as well. Concerning the latter, sufficient training opportunities and cues must not be neglected.

3.5.2 Data Entry

Entering data is an essential form of interaction especially for applications which acquire, process or communicate data such as medical, financial or simple messaging applications. Currently, software keyboards and keypads are provided to enter textual or numerical data on tablet devices. Particularly for older users it becomes difficult to complete major data entry tasks with such software keyboards within an adequate time and a minimum of mental and physical effort. Rising motor impairments like diminishing pointing accuracy lead to a slow input speed while cognitive impairments like less capacity of the working memory require more concentration to complete such tasks [Farage et al., 2012, Fisk et al., 2009]. As a consequence, if data entry is essential to an application, entry sequences (e.g., forms) and data entry task in general should be reduced an essential minimum. Apart from that, entering data can be accelerated as well as simplified by providing other options like selecting predefined values or providing buttons or sliders to increment or decrement values [Caprani et al., 2012].

INT 2.1 Keep data entry tasks to a minimum.

Choosing a most suitable input option for textual data depends on the text length on the one hand and on the user experience in using a certain keyboard layout on the other hand. Users who are experienced in using a standard QWERTY-layout on physical keyboards are able to cope with the use of a software keyboard with the same keyboard layout much faster and therefore have less problems entering longer texts. Moreover, the more experience a user has using the QWERTY-layout, the more words per minute can be entered. Novices in turn may search longer for letters on a QWERTY-layout than on an alphabetically ordered keyboard layout. Such an alphabetically ordered keyboard as well as a minimum of text entry tasks should be preferred for users with less typing experience. [Fisk et al., 2009, Nicolau and Jorge, 2012]

Although several other keyboard layouts exist (e.g., Dvorak or Neo), the QWERTY-layout is the most established. Thus, the following guideline recommends to provide a QWERTY-layout for experienced users instead of other layouts. Additionally, the assignment of the keys on a QWERTY-keyboard (which is optimized for the English language) slightly differs in other countries. Characters which are less often in other languages are swapped or replaced with more frequent ones. In Germany, for instance, the QWERTZ-layout is used, in France and Belgium AZERTY-layout. Consequently, an application should provide the country-related layout of the English QWERTY-keyboard.

INT 2.2 Regarding long textual data entry tasks on software keyboards, a country-related QWERTY-layout for experienced users should be preferred. For novices an alphabetic layout and short input sequences may be used.

Due to space constraints on small screens, the key shape and key layout of a software QWERTY-keyboard differs from a physical keyboard (cf. figure 3.7). Keys like backspace and shift which sometimes are placed at different positions and often are not textually labeled have to be searched extensively [Kobayashi et al., 2011]. Nicolau and Jorge [2012] investigated the input speed and accuracy of older people using QWERTY-layout software keyboards on touch devices. To facilitate text entry tasks for older users they propose to display keys wider than taller to prevent input errors by touching a neighboring letter (cf. section 3.2.1 for a proper sizing of buttons in general). Moreover, providing a language based error correction simplifies entering text for older users. The most common errors occurred by simply forgetting to enter single letters. The mental effort to correct such errors is reduced when correctly spelled words are suggested.

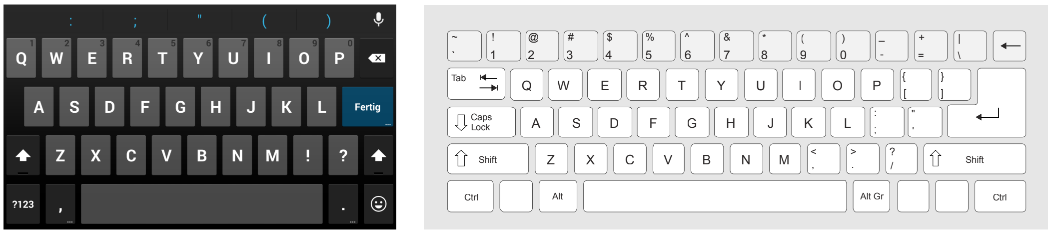

Figure 3.7: Comparison of the Standard Google Android Keyboard (Left) and a Standard Physical QWERTY Keyboard Used in the U.S.A. (Right)

> **INT 2.3** The keys of a software keyboard to enter textual data should be wider than taller and provide a language based error correction.

The lack of haptic buttons on virtual keyboards makes it difficult for experienced users to use the ten-finger typing system. Moreover, the input field is possibly hidden by the keyboard as well as the inputting arm fatigues more quickly [Caprani et al., 2012]. Since numeric input tasks are short in length and displaying the software keypad requires less space, special hardware keypads for such tasks are not necessary. Therefore:

> **INT 2.4** A hardware keyboard facilitates the entry of long text sequences.

> **INT 2.5** Software keyboards are preferable for small data input activities, especially for numeric data.

For people with significant visual impairments a voice recognition can be taken into consideration. Although it provides a high input speed, an error correction within such systems is difficult and ambient noises may interfere with the users voice [Fisk et al., 2009].

In general, different typing experiences, typing behavior and personal preferences influence which input option suites best. Thus, the opportunity to choose among a virtual or hardware keyboard as well as an alphabetical or QWERTY-layout should be provided [Nicolau and Jorge, 2012]. The importance of personalizing the applications interface is discussed in detail in section 3.7.

3.5.3 Feedback

When humans interact with computer systems, it is important that the system informs the user about the current system state. Whenever an action is performed by the user, its success or failure has to be communicated by the system. On touch device applications such feedback is possible through visual, tactile or auditory signals as well as through a combination of them. To ensure that especially older users can sense and interpret this signals properly, several age-related sensory changes have to be considered.

With increasing age, several impairments in visual perception can occur (cf. section 2.2). The color perception can be affected as well as peripheral vision and visual acuity. Guidelines to accommodate visual content for such impairments (e.g., using proper colors) have already been suggested in section 3.1 and section 3.2. Since visual feedback (while pressing buttons, performing gestures, receiving messages etc.) is omnipresent in touch applications, these guidelines have to be taken into consideration when visual feedback is developed.

A common problem regarding touch interaction is the so called “fat finger problem”. Because of the large contact area of the fingertip and the occlusion of the target by the finger, the intended target is possibly not be reached accurately and therefore missed [Holz and Baudisch, 2010]. Moreover, several models exist to detect a discrete coordinate which is nearest to the intended target [Holz and Baudisch, 2010, 2011]. Regarding older users who are affected by a tremor, reaching an intended target on the surface becomes even more difficult. Visual feedback, which indicates the perceived touch coordinate, helps older people to reach their intended target [Kobayashi et al., 2011]. Thus:

INT 3.1 Support the user by indicating the touch location with visual feedback.

At present, tactile feedback on touch devices is only possible through vibration signals. Due to the fact that the surface of these devices is plain, other haptic elements (like tangible buttons) and therefore tactile feedback opportunities are not possible yet. As mentioned in section 2.2, within age the vibration receptors within the skin and muscles to detect high frequency vibration (60 Hz and above) become less sensitive while sensing the low frequency vibrations (such as 25 Hz) is less impaired [Fisk et al., 2009]. For vibrotactile feedback within touch applications this means:

INT 3.2 Use low frequency vibration (25 - 60 Hz) for vibrotactile feedback.

Similar to haptics, hearing losses within age mainly affect high frequency (2000 Hz and above) contrary to low frequency sounds (cf. section 2.2). In section 3.4 the guidelines MMD 3, MMD 4 and MMD 5 are provided to accommodate these auditory changes concerning verbal information. As an example, male voices are better noticed than female because of the low frequency voice (cf. guideline MMD 3). The same applies to non-verbal auditory information. Low frequency sound signals should be used to convey feedback information; i.e., between 500 and 2000 Hz. However, high frequency sound signals (2000 Hz and above) can be perceived and localized better when the duration of these sounds is increased.

Another frequently occurring hearing problem is *presbycusis*, the diminishing ability to perceive low intensity sounds (i.e., quiet sounds). While younger people are able to perceive sounds below 3 dB (a whisper is around 8 dB loud), the individual threshold increases with age, which is why about 60% of people aged 55 or above already have some sort of hearing impairment. An individuals threshold exceeding 35 dB results in severe hearing impairments. It is therefore recommended to provide sound signals with a volume of at least 60 dB (a normal conversation is about 50 to 60 dB). [Farage et al., 2012, Fisk et al., 2009]

Guideline INT 3.3 briefly summarizes these findings:

INT 3.3 Auditory feedback should provide a volume of at least 60 dB and a sound-frequency of 500 - 2000 Hz. If high frequencies have to be used the duration (at least 500 ms) should be increased.

However, providing feedback on touch devices is not restricted to one type at a time (i.e., uni-modal feedback). Different cues (auditory, tactile or visual) can be combined, which is called multi-modal feedback. In fact, providing tactile feedback solely may cause rather distraction than support [Motti et al., 2013]. In general, perceiving redundant feedback signals through different sensory channels enhances the performance of older users. Through providing multi-modal feedback possible impairments of one sensory channel may be compensated when simultaneously another one is stimulated. [Lee et al., 2009, Jacko et al., 2003, Fisk et al., 2009, Farage et al., 2012]

> **INT 3.4** Multi-modal (combining audio, visual and/or tactile signals) feedback should be favored over uni-modal feedback. Especially tactile and visual feedback should not be used solely.

Feedback is used to inform the user that a previous command has to be repeated or more succeeding ones can be performed. The elderly tend to process information more slowly and take between 1,5 and 2 times longer to respond than young people. Application developers therefore should generally assume that older users perform any succeeding actions within a longer time interval. This means pop-up menus or messages, for example, should either be displayed with ample duration or must be closed explicitly by the user. [Fisk et al., 2009, Kurniawan and Zaphiris, 2005]

> **INT 3.5** Provide ample time to process information and to make a physical response.

Developers of any computer system must assume that both the user and the system are prone to errors. Irrespective of whether these errors are caused by the system or the user, clearly informing the user about the cause and consequences of the error is essential for successfully recovering from it. For older users the wording of error messages is especially important, as they are more likely to give up on a task they find difficult to perform as compared to younger users. This means, a simple language as well as avoiding technical terms (cf. section 3.3) is also a fundamental issue regarding error messages. Moreover, to prevent older users from simply overlooking error messages, they should not vary in their placement or appear inconspicuous. [Fisk et al., 2009, Nielsen, 2013]

Briefly summarized this means:

INT 3.6 Provide error messages that are informative about the error occurred, the consequences and how to recover from it. Error messages should always appear at the same location.

3.6 User Support and Training

Learning and understanding how to use new applications is essential for their successful handling. Even if the functionality of applications is provided as intuitively as possible, problems like open questions or misunderstandings may arise. Therefore, several methods are available to assist people when confronted with new applications and their functionality. Next to providing a manual, tutorials or an online help, users also can be supported in person. Especially older users rely more on the availability and comprehensibility of supportive material than the younger. Older people may suffer from cognitive changes, have doubts about their ability to learn or tend to avoid getting into new learning situations. Therefore, more help and interactive training is needed within this age group [Fisk et al., 2009]. This section covers how older users should be assisted in becoming acquainted with applications.

In general, an application should provide supportive material which is accessible at any point in time. This prevents users from getting lost within the application or reaching a point where heading back or further actions are unclear. As an example, a “Help”-button should be provided which is displayed at the same position on every application view.

SUP 1 User support must be accessible at any time and any location within the application. The user should not get into a situation where he is left on his own.

The way how user-supportive and learning material is provided and organized depends on its complexity. However, when multiple sources of such material (e.g., a printed in combination with a online manual) are provided, high mental effort is needed to combine the information from one source with another. Thus, to solve a problem or answer a question, the user should refer to as few sources as possible. [Fisk et al., 2009]

SUP 2 “Provide only one source of learning material (e.g., manual, tutorial) if possible.” [Fisk et al., 2009]

The functionality of an application can be introduced by providing an initial training (e.g., step-by-step walkthrough). Depending on the level of the users prior knowledge, such a training needs to be more or less precise regarding its information content. As an example, an e-mail client may explain the term “e-mail” to a novice before introducing more specific functionality like sending and receiving e-mails. Thus Dahn et al. [2014] suggest:

> **SUP 3** “Consider to provide the user a choice between a more comprehensive or more restricted initial training with regards to its information content.”

Furthermore, when application features are initially presented, the slower pace of older people to process information should be considered (cf. section 3.5). This implies that sufficient time and opportunities should be provided to practice or repeat a single training step. Additionally, next training steps should be triggered by the user instead of time based events. [Campbell, 2015, Fisk et al., 2009]

> **SUP 4** “Introducing application features gradually over time can be useful to prevent cognitive overload.” [Campbell, 2015]

In summary, being able to practice any functionality of touch applications is crucial for the elderly. Studies show that in combination with sufficient training opportunities even more complex gestures like multi-touch gestures can be used successfully although they are not recommended for elderly users (cf. section 3.5.1) [Kobayashi et al., 2011].

3.7 Personalizing Application Interfaces

With increasing age declines in perceptual, cognitive and psychomotorical abilities occur. This means neither that older adults show all of these declines in general nor that they occur at a certain age. While some abilities may be impaired at a certain age, other may remain intact depending on the person concerned. This is the reason why the individual capabilities vary much more among older than younger age groups. [Fisk et al., 2009]

Due to these variances of individual capabilities, it is important to compensate age-related impairments when designing applications for the elderly, as much as possible. At the same time, unnecessary adaptions which may disrupt the usability of applications should be avoided. For example, to older people without hearing impairments a loud acoustic feedback (cf. section 3.5.3) may be annoying. An application which offers a number of adjustable factors, allows to be customized to individual needs and preferences.

PER 1 Adjusting certain factors of an user interface (e.g., the font size) to personal needs is important for the elderly.

The specific factors which should be adjustable by the user vary with the provided functionality of the application. For example, when an application requires reading long texts, different font sizes (cf. section 3.2.1) should be offered. Additionally the size of graphics or buttons should be modifiable when these are essential for user interactions. The following guideline summarizes several other factors, which are recommended by different authors to be adjustable [Loureiro and Rodrigues, 2014, Dahn et al., 2014, Darroch et al., 2005]:

PER 2 Consider to make some of the following factors adjustable:

- the size of font, graphics or targets,
- the combination of audio, tactile and visual feedback,
- the way data is entered (software or physical keyboard),
- the range of application functionalities,
- style information like background images or colors.

If too many of these factors can be modified by the user, customizing the application possibly becomes too complicated on the one hand. On the other hand, the less possibilities an application provides for personalization, the more restrictions regarding individual preferences have to be accepted by the user. Thus, a balance between simplicity and personal needs has to be made.

3.8 Summary

In this chapter, 58 literature based guidelines were elaborated, discussed and grouped into seven different guideline categories. To give a brief overview, the following section 3.8.1 lists all seven categories, the corresponding subcategories and guidelines in the order of their occurrence.

Because these guidelines cover a large amount of possible use cases, developing senior-friendly applications rarely requires the realization of every single guideline. In fact, the use case and scope of function of an application influences which guidelines are reasonable to be brought into practice. This may also mean, that in some cases it makes sense to concentrate on applying just a few of these guidelines. Moreover, depending on the use case and available development resources (i.e., time, money and personnel) the cost-benefit factor of a guideline differs. The implementation effort of some guidelines is not worth the benefit it brings for a better usability of an application interface. As an example, an application to access data within a complex information structure (e.g., a search engine) requires more concentration on a good menu structure than on the design of appropriate and meaningful icons.

In chapter 4 an application scenario is presented, which takes a close look on the selection of guidelines to be realized as well as on the realization process itself.

3.8.1 Overview of Guidelines

This section gives a review on the guidelines pointed out in the previous chapter 3. The organization of the guideline categories is illustrated in figure 3.8.

Design

1. Color

   DES 1.1 Use colors of the long wavelength end of the spectrum (i.e., warm colors like red or yellow) if the color carries information – avoid blue especially.

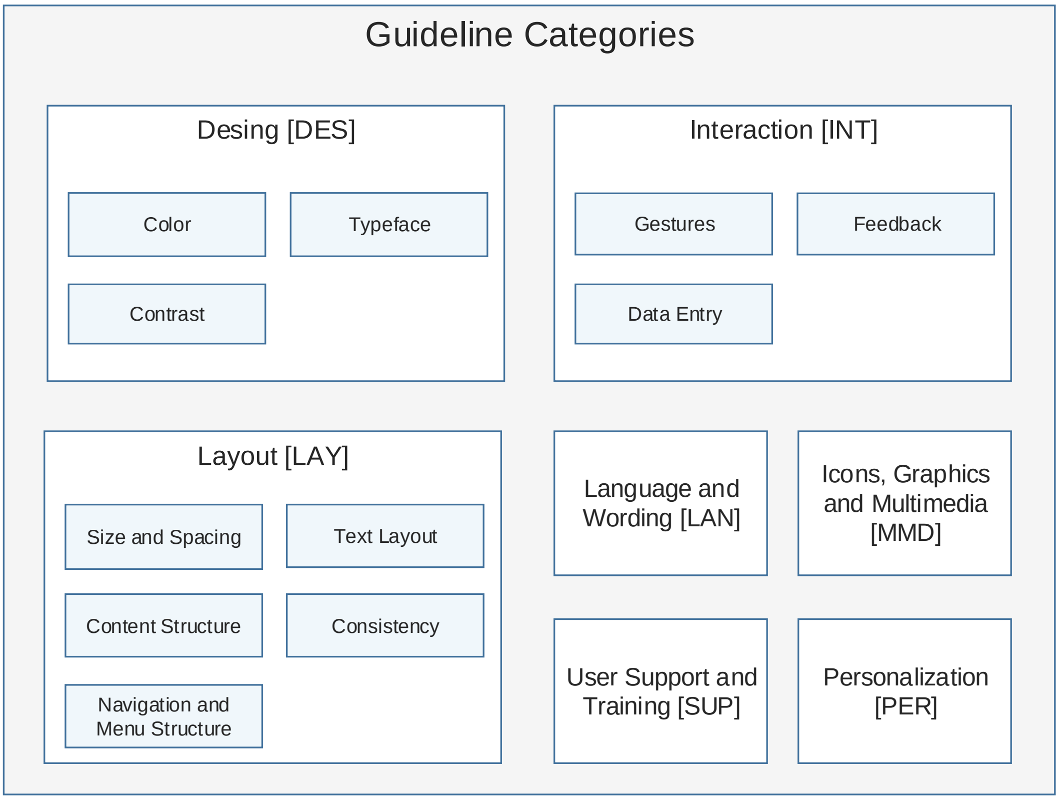

Figure 3.8: Guideline Structure

DES 1.2 Colors should be used conservatively. Use colors to carry important and relevant information (e.g., warnings, grouping elements).

DES 1.3 Keep in mind that dark background colors increase glare and highlight fingerprints.

DES 1.4 Avoid colored and patterned backgrounds for text display areas.

2. Contrast

DES 2.1 To ensure legibility the color contrast ratio of text smaller than 18 pt should be at least 7:1 or 4,5:1 for large text or decorative text (following the formula provided by W3C [2008]).

3. Typeface

    DES 3.1 Use sans serif font types (e.g., Verdana or Arial).

    DES 3.2 Avoid decorative, italic, underlined and condensed font styles. Use bold font types and uppercase text only for highlighting key terms.

Layout

1. Size and Spacing

    LAY 1.1 Buttons, clickable icons and labels should range in size between 11,43 mm square minimum and 19,05 mm square maximum. Adjacent buttons used in rows (e.g., keypad) should be at least 16,51 mm square (cf. Table 3.1).

    LAY 1.2 The spacing between adjacent buttons in a row should reach from 3,17 mm to 12,7 mm maximum (cf. Table 3.2).

    LAY 1.3 Font sizes for multiple line text (i.e., primary text) should range between 9 pt and 14 pt and depend on screen size and the visual acuity of the user.

    LAY 1.4 An 1.5 line spacing up to double spacing increases readability of text.

2. Text Layout

    LAY 2.1 Keep text lines short in length: The amount of characters per line for primary text should range between 60 and 75.

    LAY 2.2 Avoid the need of scrolling to read a text. Rather consider to decrease the font size or line spacing.

    LAY 2.3 Avoid moving text like automatic scrolling.

    LAY 2.4 Multiple line text should be left justified.

    LAY 2.5 Provide clear and large headings.

3. Content Structure

   LAY 3.1 Simplicity of visual perception is key: Avoid visual clutter, distracting visual stimuli and non-relevant information due to the declining visual field.

   LAY 3.2 Minimize working memory demands: Keep the number of information blocks presented or processed at once limited to around 5.

4. Consistency

   LAY 4.1 Consistent design is even more important for the elderly than it is for younger people. Therefore, the location of items and functions should remain the same across views and similar functions should act the same way throughout the application.

5. Navigation and Menu Structure

   LAY 5.1 Group information and actions into meaningful and clearly worded categories. The difference between the options should be apparent.

   LAY 5.2 Provide a clear and consistent navigation by displaying precise navigation cues and actions that are readily visible and accessible.

   LAY 5.3 The current location in the application should be obvious to the user all the time.

   LAY 5.4 Avoid deep hierarchies in menu structures hence the user does not get lost in the application.

   LAY 5.5 Minimize the number of steps to complete a task as well as the number of control-elements to increase the probability of successfully completing the task.

   LAY 5.6 "Don't force the user to keep information in mind for too long to accomplish a single task." [Fisk et al., 2009]

Language and Wording

LAN 1.1 Language should be simple and clear. In addition, it should use active voicing and positive phrasing.

LAN 1.2 Phrasing assuming prior knowledge (e.g., technical terms) or a certain (especially young) age of the user should be avoided. Provide a glossary if technical terms are necessary.

Icons, Graphics and Multimedia

MMD 1 Well designed or familiar symbols and icons can be more effective ways to convey information than text messages.

MMD 2 Where possible provide a label or text for icons or illustrated instructions.

MMD 3 "Speech rate of verbal information should be kept to 140 words per minute or less, male voices should be preferred to female voices and synthesized speech should be as natural as possible." [Fisk et al., 2009]

MMD 4 "Consider providing parallel visual and auditory presentation of language" (i.e., subtitles or a text-to-speech function) [Fisk et al., 2009].

MMD 5 "Limit your sounds to one at a time; for example, speech over music may be hard to distinguish." [Holt, 2000]

Interaction

1. Gestures

   INT 1.1 Instructions, training opportunities and clear visual clues facilitate memorizing and familiarizing gestural actions.

   INT 1.2 "Prefer indexical and manipulative gestures over symbolic and iconic gestures" (following the gesture categorization by Stößel [2012]).

INT 1.3 “Favor familiarity of a gesture pattern over its execution efficiency” [Stößel, 2012]

INT 1.4 “Avoid alphanumerical gestures.” [Stößel, 2012] (e.g., drawing an “C” for “copy file”).

INT 1.5 Turning over pages (like through “Next”- and “Previous”-buttons or swiping) should be preferred to scrolling up or down.

INT 1.6 Avoid drag and drop operations and double touch gestures.

INT 1.7 “Accommodate for slower gesture execution for time-critical events (e.g. multitap latencies). Movement is slowed by 1,3 compared with younger users.” [Stößel, 2012]

INT 1.8 “Employ curved gestures sparsely.” [Stößel, 2012]

INT 1.9 Multi-touch gestures are not recommended for older users.

2. Data Entry

INT 2.1 Keep data entry tasks to a minimum.

INT 2.2 Regarding long textual data entry tasks on software keyboards, a country-related QWERTY-layout for experienced users should be preferred. For novices an alphabetic layout and short input sequences may be used.

INT 2.3 The keys of a software keyboard to enter textual data should be wider than taller and provide a language based error correction.

INT 2.4 A hardware keyboard facilitates the entry of long text sequences.

INT 2.5 Software keyboards are preferable for small data input activities, especially for numeric data.

3. Feedback

INT 3.1 Support the user by indicating the touch location with visual feedback.

INT 3.2 Use low frequency vibration (25 - 60 Hz) for vibrotactile feedback.

INT 3.3 Auditory feedback should provide a volume of at least 60 dB and a sound-frequency of 500 - 2000 Hz. If high frequencies have to be used the duration (at least 500 ms) should be increased.

INT 3.4 Multi-modal (combining audio, visual and/or tactile signals) feedback should be favored over unimodal feedback. Especially tactile and visual feedback should not be used solely.

INT 3.5 Provide ample time to process information and to make a physical response.

INT 3.6 Provide error messages that are informative about the error occurred, the consequences and how to recover from it. Error messages should always appear at the same location.

User Support and Training

SUP 1 User support must be accessible at any time and any location within the application. The user should not get in a situation where he is left on his own.

SUP 2 "Provide only one source of learning material (e.g., manual, tutorial) if possible." [Fisk et al., 2009]

SUP 3 "Consider to provide the user a choice between a more comprehensive or more restricted initial training with regards to its information content." [Dahn et al., 2014]

SUP 4 "Introducing product features gradually over time can be useful to prevent cognitive overload." [Campbell, 2015]

Personalization

PER 1 Adjusting certain factors of an user interface (e.g., the font size) to personal needs is important for the elderly.

PER 2 Consider to make some of the following factors adjustable:

- the size of font, graphics or targets,
- the combination of audio, tactile and visual feedback,
- the way data is entered (software or physical keyboard),
- the range of application functionalities,
- style information like background images or colors.

4 Application Scenario

Based on the usability guidelines discussed in chapter 3, a tablet-application was developed to be tested and evaluated by a group of people older than 64 years. In this way, it can be verified whether an appropriate deployment of these guidelines actually supports the elderly in using the application independently and satisfyingly. The conduction of such a usability test is described in chapter 5, whereas this chapter focuses on the development process of the application.

At first, the use case and basic functionality of the application are discussed in detail in section 4.1. This includes the description of the applications range of functions as well as the navigation structure. A detailed view on how guidelines are applied to the application is given in section 4.2. Section 4.3 focuses on the technical design of the application and provides an insight into its implementation.

4.1 Basic Idea and Application Structure

At the beginning of the design process an application concept has to be found with a use case designed to suite the needs of elderly people. Therefore, the application should have a simple, familiar and supportive use case. This is especially important for the evaluation of the application when carrying out a study (cf. chapter 5). If the purpose of an application is apparent to the user, it is rather accepted and the functionality is less misunderstood (cf. section 2.4). In addition, the participants attitude towards the application has less negative influence on its evaluation within a study.

For this reason, the main purpose of the application developed in this context is to plan and review the events of a day. Functionality of a calendar, a phone book as well as a diary are included into the *Tagesplaner*-application (translated from German: *Dayplanner*). A day can be planned by creating and managing appointments as well as tasks. Furthermore, it is possible to record other events of a day by creating notes. Contacts can be managed and directly called from within the application. The *Tagesplaner*-application shows these appointments, tasks and notes as well as telephone calls in their chronological order for every day (i.e., similar to a diary).

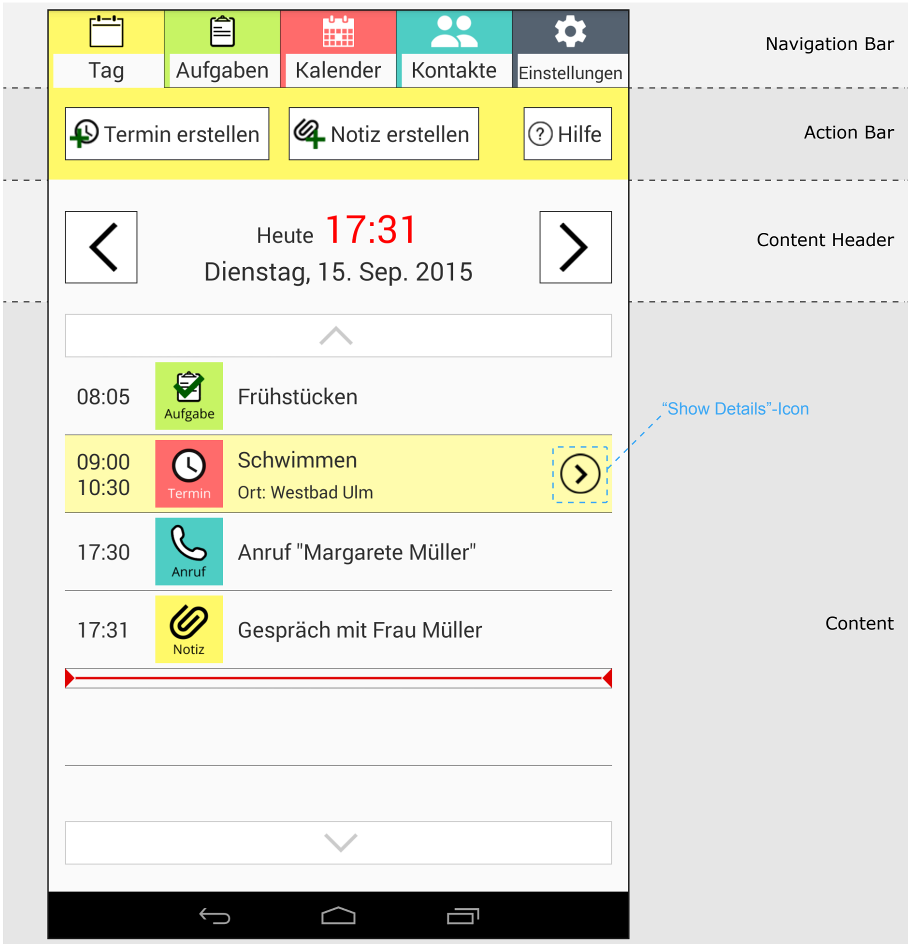

Figure 4.1: Screenshot of the of the *Tag*-View and Basic Layout of the *Tagesplaner*-Application.

Figure 4.1 shows a screenshot of the start screen combined with the basic layout structure of the *Tagesplaner*-Application. At the top of this screenshot the navigation bar is displayed. This navigation bar consists of five tabs: *Tag* (translated: day), *Aufgaben* (translated:

tasks), *Kalender* (translated: calendar), *Kontakte* (translated: contacts) and *Einstellungen* (translated: settings). These tabs are located at the same position in each view and can be switched independently from the currently selected tab.

As shown on the screenshot in figure 4.1 within the *Tag*-view appointments, notes and accomplished tasks of a certain day are displayed in their chronological order within a list. Because the *Tag*-view only shows tasks which are already marked as “Done”, it gives no opportunity to manage ones which still have to be accomplished. This can be done by selecting the *Aufgaben*-view (cf. figure 4.2). This view presents all stored tasks which have to be accomplished at the selected day. By selecting a task and touching the “Show Details”-icon (cf. figure 4.1), this task can be marked as “Done”. The task is then not shown in the *Aufgaben*-view anymore and a new list item for the accomplished task appears in the *Tag*-view.

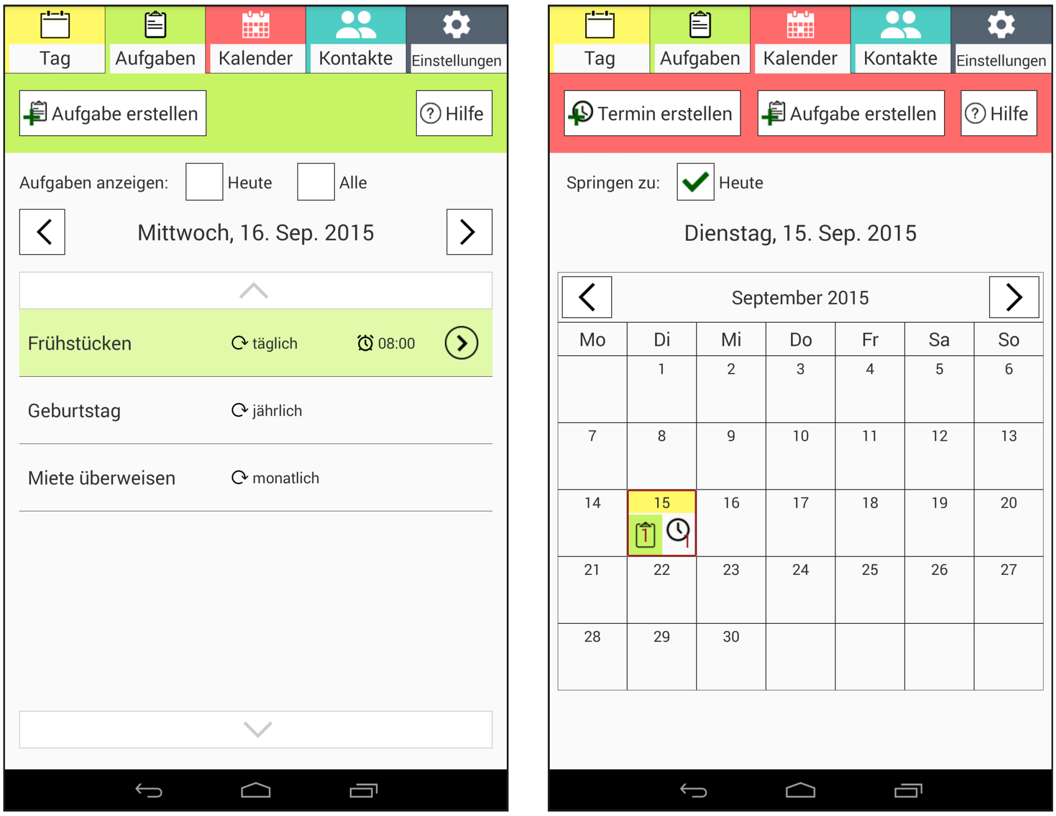

Figure 4.2: Screenshots of the *Aufgaben*-View (Left) and *Kalender*-View (Right).

Within this first two views (i.e., *Tag* and *Aufgaben*) the previous or next day (regarding the currently displayed day) can be selected by touching the “Left”- or “Right”-arrow above each list. To select a specific day more quickly, with the *Kalender*-view (cf. figure 4.2) a calendar is available which displays the current month by default. The day selected via this calendar stays the same, when the user switches back to the *Tag*- or *Aufgaben*-view. The same applies to the day that is selected in both of the latter views.

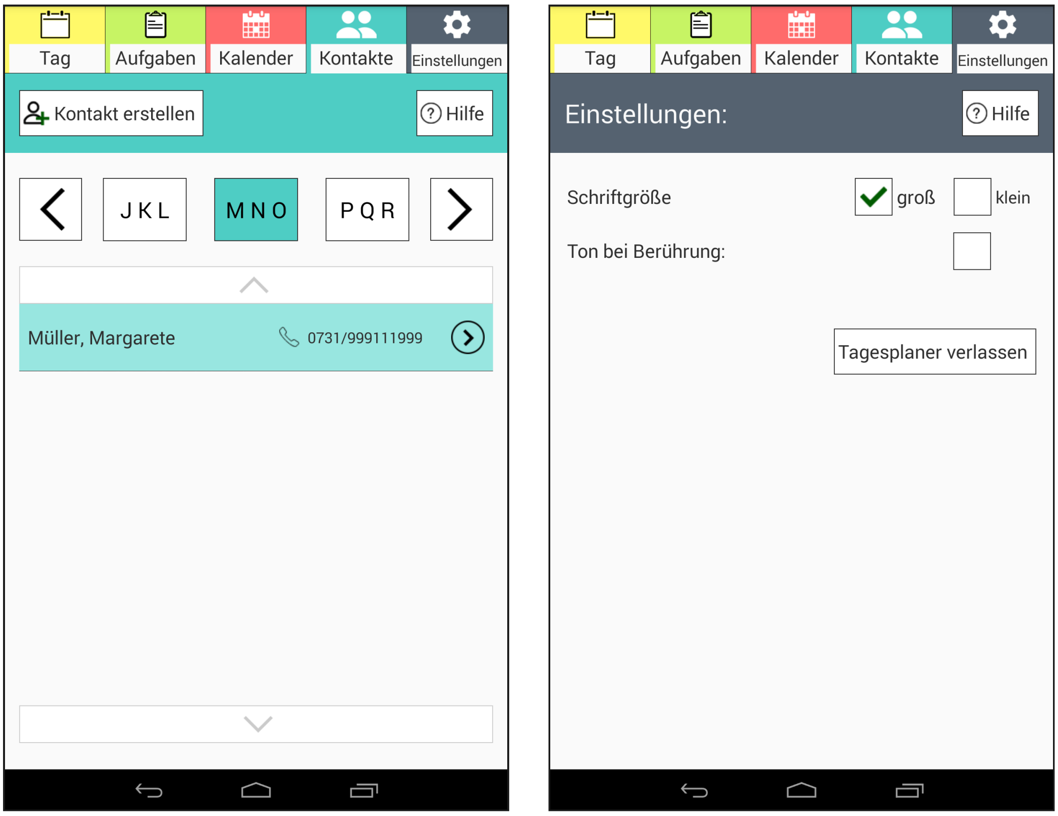

Figure 4.3: Screenshots of the *Kontakte*-View (Left) and *Einstellungen*-View (Right).

Within the *Kontakte*-view (cf. figure 4.3) all contacts stored on the device are sorted alphabetically by their surname based on letter groups (e.g., from A to C and D to F). When a certain contact is selected its details can be displayed by pressing the "Show Details"-icon (similiar to showing the details of a task) and a button provides the opportunity to simulate a phone call to the contacts telephone number. The initialization of a real telephone connection is not implemented in this application, since this function has not to be necessarily tested within the study. When such a simulation of a telephone call was performed, a new list item for the current day in the *Tag*-view is added which indicates the current time and name of the phoned contact (cf. figure 4.1).

The screenshot on the right in figure 4.3 shows the view to personalize the application. The *Einstellungen*-view provides the opportunity to change the font size and to en- or disable a audible feedback (i.e., a sound is played on button touches).

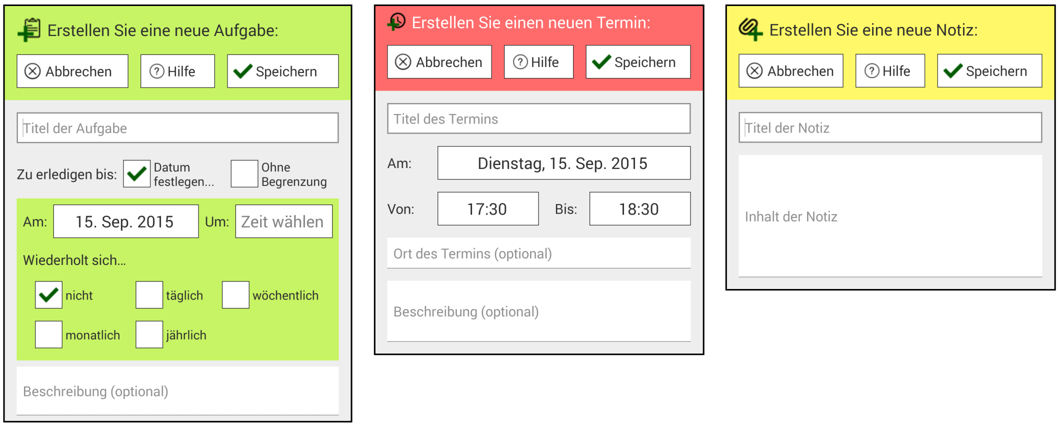

Figure 4.4: Screenshots of the Dialogs to Create a Task, an Appointment and a Note (from Left to Right).

The items which can be managed by the *Tagesplaner*-application are appointments, tasks, notes and contacts. Via the five views mentioned above, each of these objects can be created by calling the corresponding dialog. Figure 4.4 shows these dialogs to create a task, an appointment and a note. To give a brief overview of the range of functions of the *Tagesplaner*-application, table 4.1 summarizes the actions implemented to manage these items.

Item	**Actions**
Appointment	Create, Delete, Change Date, Change Time
Task	Create, Delete, Change To-Do-Date, Mark as "done"
Note	Create, Delete, Edit Content
Contact	Create, Delete, Simulate Phone Call

Table 4.1: Actions Implemented to Manage the Items of the *Tagesplaner*-Application

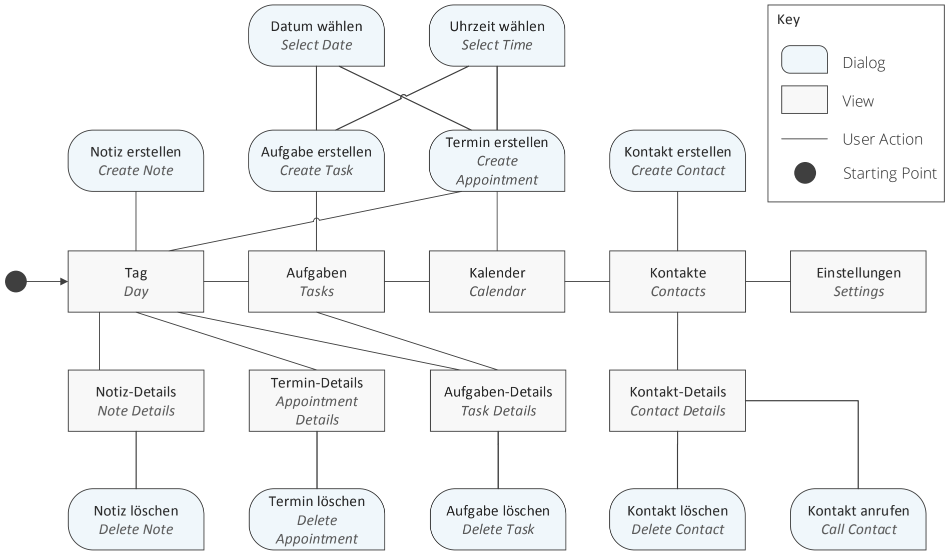

Figure 4.5: Navigation Structure of the *Tagesplaner*-Application

The navigation structure in figure 4.5 shows how four dialogs mentioned above (displayed in the second level of the diagram) can be reached from the main views (displayed in the third level). The dialog to create a new appointment, for example, can be reached via the *Tag*- as well as the *Kalender*-view. A new note, in turn, can only be created starting at the *Tag*-view.

At the fourth level of figure 4.5 the *Details*-views are depicted which can be reached by touching the corresponding “Show Details”-icons. These views, in turn, provide buttons to delete the current item (i.e., an appointment, note, task or contact) or to edit its data. For instance, an appointment can be moved to another day by simply editing its date. The dialogs to confirm whether an item should be finally deleted are shown in the fifth level of the navigation structure.

4.2 Applied Guidelines

To provide the basic functionality described in the previous section 4.1 in a senior friendly way, the guidelines listed in chapter 3 are taken into consideration. This section describes how these guidelines are put into practice. As mentioned in section 3.8, the priority and significance of the guidelines are bound to the application context. Therefore, in this case some guidelines are consciously omitted (e.g., MMD 3 for speech signals). Others can not be applied consequently, due to hardware restrictions of the target device (e.g., display size, absent tactile output functions). Such difficulties are discussed as well in the following paragraphs grouped by the guideline categorization from chapter 3.

4.2.1 Design

The *Tagesplaner*-application avoids the use of colors to carry key information (cf. DES 1.1). Although the application does not renounce colors completely, symbols and textual information can be detected and distinguished without perceiving their colors. Figure 4.6 shows the colors used in the application. These are only used to differentiate the icons symbolizing appointments (red), notes (yellow), tasks (green), contacts (blue) more quickly and not purely for decorative purposes (cf. DES 1.2). The same colors are used to indicate the currently selected tab (*Tag*: yellow, *Aufgaben*: green, *Kalender*: red, *Kontakte*: blue and *Einstellungen*: dark blue). The main background color of the application is kept in a very light grey (cf. figure 4.6) and no background pattern is used (cf. DES 1.3 and DES 1.4).

	Color Value	Tabbed Navigation	Interface-Elements
	#FFF969	*Tag*-view	Note
	#C7F464	*Aufgaben*-view	Task
	#FF6B6B	*Kalender*-view	Appointment
	#4ECDC4	*Kontakte*-view	Contact
	#556270	*Einstellungen*-view	
	#FAFAFA		Background Color
	#2E2E2E		Text Color

Figure 4.6: Color Values and Usage of the Colors in the *Tagesplaner*-Application.

Textual information is either displayed on the application-background (color contrast ratio: 13,01:1) or on a plain white background within buttons and text fields (color contrast ratio: 13,58:1). As guideline DES 2.1 proposes a color contrast ratio of at least 7:1, their legibility is ensured. Moreover, a sans serif font type is used in the application (Roboto [Google Inc., 2015]) and special font styles (e.g., bold or italics) are omitted in the application.

4.2.2 Layout

Taking guideline LAY 1.1 into account, the smallest button in the application is 8,64 x 8,64 mm in size (buttons to select the next or previous day on the *Aufgaben*-view), the largest 7,0 x 88,9 mm (buttons to scroll a list up or down). To enter textual data the standard Google Android keyboard is used (cf. figure 4.7) where the keys are 7,1 x 9,5 mm in size. These values are measured when the application runs on a device with a 7 inch screen (Google Nexus 7). Due to the lack of space, the buttons on the portrait-mode keyboard could not be increased in size. To avoid erroneous button touches the minimum spacing between adjacent buttons (e.g., between the buttons *Termin erstellen* and *Notiz erstellen* in the *Tag*-view in figure 4.1) is never smaller than 3,14 mm (cf. LAY 1.2). The main font size used in this application is 10 pt. The smallest font size of 8 pt is used to display further information within a list item (e.g., the phone number in the *Kontakte*-view or the location of an appointment within the *Tag*-view (LAY 1.3).

Figure 4.7: Screenshot of the Standard Google Android Keyboard.

A simple content structure within each view allows the user to focus on certain information (cf. LAY 3.1). As depicted in figure 4.1, each view (except the *Einstellungen*-view) is divided into four parts (cf. LAY 3.2). At the top of the screen the *Navigation Bar* forms with its five items the first block. The second part of each view is the *Action Bar*, which indicates with its background color the currently selected tab. Within this action bar the buttons to create new items as well as a help button on the outer right of the screen are displayed. Between the action bar and the *Content* (containing either a list or a calendar) the *Content Header* shows the selected day together with the buttons to change the day. Within the *Kontakte*-view, instead of a selected day, the buttons to select a letter group are displayed. Items of these views, in turn, do not contain more than four elements at a time.

Because the four information blocks (i.e., the navigation bar, action bar, content header and content) are arranged in the same order within each view, consistency in design of these views is achieved (cf. LAY 4.1). Furthermore, within the dialogs the action bar of the basic views reoccurs and is displayed in a similar form. It is also located at the top of a dialog and its background color again indicates the specific item that can be created by this dialog (e.g., the dialog to create an appointment has a red header, as shown in figure 4.4). Each dialog provides a "Cancel"-, "Help"- and "Save"-button in the same order respectively. The corresponding *Details*-views of selected list items are organized in a similar way. They contain an action bar again followed by a grid view containing the corresponding information. Consistency is not only realized by the content structure of similar views, but also by the style of similar elements and the provided interaction possibilities. The buttons, for example, are styled consistently throughout the entire application and are simply recognizable by their black border. Additionally, interacting with the lists and their items (e.g., showing the *Details*-view for a selected item) is realized in the same way for every list in the application.

Since the concept of a tabbed navigation is easy to understand and apparently shows the current location to the user, it was chosen to fulfill guideline LAY 5.2 and LAY 5.3. The menu itself (i.e., the tabbed navigation) is therefore structured in a flat hierarchy consisting of just one hierarchy level (cf. LAY 5.4). As shown in figure 4.5, the navigation structure concerning the possible user actions within the tabs does not consist of more than three hierarchy levels either. Additionally, the number of steps to complete a single task is reduced to a minimum (cf. LAY 5.5 and LAY 5.6). Creating an appointment, for example, takes six steps: Select desired day, press "Create Appointment"-button, insert title, select start time, select end time, press "Save"-button.

4.2.3 Language and Wording

As the application is tested by test persons from Germany, no English terms are used. Moreover, the simple application scenario does not require the use of technical terms and language is kept simple (cf. LAN 1.2). Buttons (except “Next”-, “Previous”-, “Up”- and “Down”-buttons) are labeled with a description of the action it causes (cf. LAN 1.1). For instance, the button to create a new task is labeled “Create Task” instead of “New Task”.

4.2.4 Icons

In this application, icons were used to emphasize the meaning of terms, actions and menu-items (MMD 1). Figure 4.8 shows these icons at a glance. Source of these icons is the online search engine for icons *Iconfinder* [Iconfinder, 2014]. While it is easy to find familiar and unambiguous symbols for “Cancel”, “Help”, “Delete”, “Contacts”, “Settings” and “Calendar”, depicting a task, an appointment or a note turns out to be far more difficult. Especially representing the *Kalender*- and *Day*-view with simple, clear and distinguishable icons is challenging, as well as the “Show Details”-action for list items. Therefore, icons are as often as possible combined with a label, to explain their meanings (MMD 2).

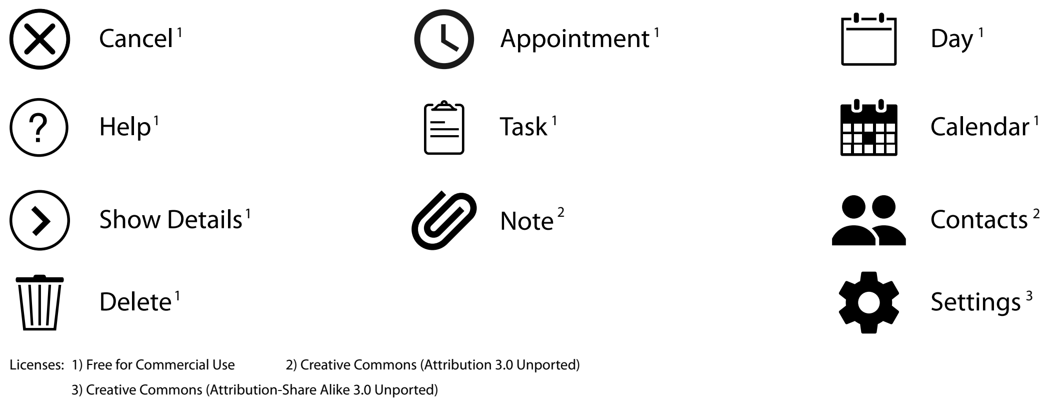

Figure 4.8: Icons Used in the *Tagesplaner*-Application.

4.2.5 Interaction

The application can be operated using only one single interactive gesture – the *Single Touch* gesture (cf. figure 3.6). No other gestures have to be known beforehand or learned in order to use the application (cf. INT 1.3). Only the interaction with the list-views constitutes an exception. Because guideline INT 1.5 recommends using “Next”- and “Previous”-buttons instead of scrolling gestures, all list views in this application provide buttons on top and below the lists to scroll up or down by a single item. To investigate which interaction method the elderly rather use, both the scrolling gesture as well as the "Up"- and "Down"-buttons can be used to interact with the list. Furthermore, list items should provide the possibility to show their details. A possible implementation of this function would be to show the *Details*-view by simply tapping on the item. However, when a single tap on a list item happens accidentally (because the user does not scroll accurately or just touches the item when pointing on it), the resulting *Details*-view showing up may irritates the user. Another implementation of this issue would be to perform the action by a double touch, which in turn is not recommended by guideline INT 1.6. Therefore, the details of a list item can be displayed by two sequentially performed single taps. The first one to select the respective item, the second one on the "Show Details"-icon which is now displayed on the right of the item.

The simple use case of the application prevents the user from entering long data sequences (cf. INT 2.1). Because only short textual data has to be entered (e.g., a title or description), the standard software keyboard of the target device is used for data input (cf. INT 2.5). To select a date or time, the standard Google Android widgets *Time Picker* and *Date Picker* are used (cf. figure 4.9).

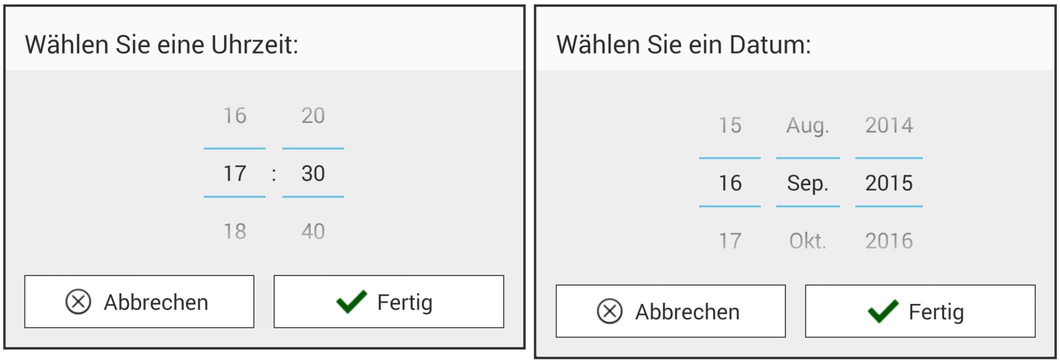

Figure 4.9: Screenshots of the Standard Google Android Widgets *Time Picker* (Left) and *Date Picker* (Right).

Tactile feedback is not implemented, due to the lack of a vibration function of the device used for application development. The auditory feedback in this application has the pitch level of a treble e and therefore the frequency of around 659 Hz (cf. INT 3.3).

4.2.6 User Support

To fulfill guideline SUP 1 a “Help”-button is displayed on each view and dialog within the action bar (cf. section 4.2.2). When testing the application by conducting a study, it is more important to investigate whether the participants are able to detect where to get help than observing how they use the support provided. Hence, no support content is displayed after pressing a “Help”-button, but the user is asked to refer to the testing person.

4.2.7 Personalization

Within the *Einstellungen*-view the application provides two options to adjust the font size and to en- or disable the auditory feedback (PER 2). Auditory feedback is disabled by default. The font size can be changed to a smaller (9 pt) than the default size (10 pt). It is not possible to choose a bigger font size, since the labels of several buttons (e.g., the buttons within the action bar of the *Kalender*-view) would be too big to fit into the buttons.

4.3 Technical Design

The *Tagesplaner* is implemented as Google Android application using the Google Android SDK 6.0 (API Level 23) [Android Open Source Project, 2015b]. The target development device is a Nexus 7 with a 7-inch display, a pixel resolution of 1920 x 1200 and a display pixel density of 323 ppi [ASUSTeK Computer Inc., 2013].

The Joda-Time library for Java [Joda.org, 2015] is used to manage time critical data within the application (e.g., calculating the calendar within the *Kalender*-view) by replacing the standard Java Date and Time classes.

5 Study Design

The previous chapter 4 describes the development of an application suitable for the elderly with the aid of the proposed guidelines. The question arises whether the realization of these guidelines actually supports the elderly in understanding and handling the application and its functionality. This can be investigated by conducting a usability test with a group of suitable test persons. This chapter presents how a qualitative study is set up and conducted to analyze the *Tagesplaner*-application (cf. chapter 4) regarding its usability. Several preconditions and considerations for a study with a target group of exclusively elderly are described in section 5.1. The aim of the study is formulated in section 5.2 in detail, followed by the discussion of the test setting and the interview setup in section 5.3. After recruiting suitable test persons (cf. section 5.4) and conducting the study, the observations are reported in section 5.5. Finally, section 5.6 reviews the findings of this study and discusses possible improvements.

5.1 Performing Usability Tests with the Elderly

When conducting a usability test with elderly participants, age-related physical and cognitive impairments (cf. section 2.2) are of particular importance. Therefore, Silva and Nunes [2010] derived 21 guidelines how usability tests with elderly participants should be designed and performed. The authors divided these guidelines into three groups. Since older adults often feel overtaxed in testing situations, the first group (*User Drive and Control*) includes guidelines to strengthen the participants confidence. Therefore, it is important to inform the participant about the purpose of the experiment, the required steps and (when the test is over) some test details. The participant should receive an overview of the experiment and its components. The second group (*Test Settings and Preparation*) concentrates on the influence of cognitive and physical limitations of the elderly during the study. Due to the often occurring limited mobility, the elderly should not be asked to move during the test. Moreover, the test should be kept short in time and offer the opportunity for breaks. The third group of guidelines is called *Care, Communication and Listening*. Within this group the authors present proposals to “improve the communication with older adults and on how to develop an emphatic relationship with them” [Silva and Nunes, 2010]. Hence, it is important to make clear that not the participant is being tested but the application itself. Besides, it is important to give the participants sufficient time to think and to use a simple language omitting technical terms as far as possible.

Bearing these guidelines in mind, the study to test the usability of the *Tagesplaner*-application (cf. chapter 4) is designed and conducted.

5.2 Study Goal

Keeping section 5.1 in mind, it is impractical to conduct a single study to verify the specific benefit of every single considered guideline in this application. Apart from that, the guidelines are conducted from existing studies and therefore already proved individually (cf. chapter 3). Hence, the aim of this study is primarily to investigate whether the way these guidelines are brought into practice actually support the elderly in using the application. For example, because of LAY 1.3. (font size) in combination with DES 2.1. (color contrast ratio), it is expected that the participants do not judge the font size as too small and illegible. Therefore, no major problems reading textual information in the application should occur. These assumptions can be verified by questioning each participant about the individual experiences concerning different usability topics.

5.3 Test Settings

To test the usability (cf. section 2.1) of the application developed in the context of this thesis, a qualitative study was set up. In this way, the personal opinion as well as the occurrence of difficulties when using the application can be recorded more individually and therefore more precisely. This is beneficial when older people are participating in the study. Because of the high variability of individual capabilities (i.e., perceptual, cognitive and psychomotorical) and previous knowledge in using touch devices, a qualitative interview can pay more attention on the participants personal needs than in a quantitative survey.

Before the participants can be interviewed, they have to test the the application. Therefore, the interviewer initially introduces the application and its organization and functionality. To ensure that each test person gains the same level of experience and knows the same amount of functionalities, they have to complete a tutorial. This tutorial consists of two different scenarios which both cover the same functionalities: Create a task, mark a task as “Done”, call a contact, create an appointment, edit an appointment and create a note. The purpose of the first scenario is to familiarize the participant with the application, the second to repeat and internalized the processes learned. During these training scenarios the test persons are observed by the interviewer and their progress documented using a voice recorder. These records are used to reconstruct the origin of possible problems occurring.

After completing the tutorial, the participants experiences are recorded by an interview. At first, the level of previous knowledge is inquired concerning the use of tablets and or other touch devices. This information is obtained to draw conclusions about how this knowledge influences the handling of the application. To receive information about the participants first impression of the application, a question asks for issues he/she likes or not.

The next part of the interview analyzes the realization of the guidelines concerning certain design issues by asking whether the font size, icons or other interface elements are discernible and displayed in an appropriate size. Moreover, when asking if the application is self-explanatory, conclusions about the information structure can be drawn. The navigation and menu structure is proven by the question: “Did any situation occur during the test where you lost track or could not orient yourself anymore?”. Due to guideline MMD 2, nearly all icons in the application are combined with a label (cf. section 4.2.4). Thus, the interview takes into consideration whether these labels are clearly worded and support the user in understanding the icons. Moreover, section 4.2.5 mentions the possibility of scrolling list elements via a scrolling gesture as well as through the “Up”- and “Down”-buttons. Although according to guideline INT 1.5 the use of scrolling gestures is not recommended, this implementation offers an interesting insight in which interaction method the elderly rather use in this context. In addition, since the standard widgets to enter dates and times are used as well as the default Google Android keyboard, the test persons are asked about their opinion on these input methods.

In general, the guidelines often describe technical and abstract aspects of an application which mostly are incomprehensible for older people. Therefore, the questions of the interview do not ask directly for certain design issues, but for the impact of the guidelines realized. This is reached when, on the one hand, technical terms are avoided and when the question focuses on the intention of the guideline on the other hand. For example, instead of asking: “Do you think the application was consistent in design?” one of the questions was: “Did any situation occur where you missed a button or functionality?”.

Furthermore, in order to set up the study as comfortable as possible for the elderly, most of the guidelines by Silva and Nunes [2010] were applied (as mentioned in section 5.1). Interview form and scenarios can be found in Appendix B and C.

5.4 Recruiting

In order to recruit suitable test persons, several pensioners were contacted via the institution “ZAWiW” (Zentrum für Allgemeine Wissenschaftliche Weiterbildung) of Ulm University. Because this institution organizes several education programs for adults – especially elderly – at the university, suitable as well as interested participants could be found quickly. What needs to be considered, however, is that in this way older people with an academic background are reached more likely. As a result, 12 participants were found, 8 female and 4 male. The youngest test person was 64 years old, the oldest 81 and the average age was about 71,8 years.

5.5 Evaluation and Discussion

After conducting the study with the 12 recruited participants, the interviews were analyzed and evaluated. The following five sections group and discuss the results and observations according to the guideline categories presented in chapter 3. Section 5.5.1 combines the findings concerning the guidelines applied to optimize design and layout issues for the elderly. The succeeding sections discuss how the chosen terms (cf. section 5.5.2), the way the icons convey information (cf. section 5.5.3), the provided interaction methods (cf. section 5.5.4) and the availability of support and training (cf. section 5.5.5) influence the usability. Finally, the discussed results and observations are summarized in section 5.5.6.

5.5.1 Design and Layout

One of the interview questions asked whether the textual information is discernible and easily readable. For 10 out of 12 test persons the applications basic font size of 10 pt was ideal. Only one of these 10 participants used the setting within the *Einstellungen*-view to display a smaller font size (9 pt). Two participants, however, preferred a larger font size for improved readability, especially reading labels of 8 pt in size (e.g., the phone number on the *Kontakte*-view – cf. figure 4.3) were difficult to read. Reading texts of this size for a longer time would be too exhausting, as one person said. Thus, when using a 10 pt font size combined with a proper color contrast ratio, reading textual information in applications is unproblematic for most of the elderly tested.

In addition, this study showed that the buttons of the *Tagesplaner*-application (designed considering guideline LAY 1.1) are displayed in a proper size. Most participants (9 out of 12) judged the buttons and clickable areas to be optimal in size and did not wish larger ones. Concerning their size, only the buttons of the software keyboard were found to be too small to many participants (cf. section 5.5.4). This confirms the correctness and importance of guideline LAY 1.1, since the buttons of the keyboard do not satisfy this guideline.

By using tabs, a simple navigation structure is provided within the *Tagesplaner*-application (cf. section 4.2.2). This is confirmed by the participants. 9 out of 12 test persons stated that they did not lose track within the application and the current location was always clear. The working principle of the tabbed navigation was clear to all the participants. However, some test persons occasionally could not detect whether a tab was already selected or not. For example, when the participants wanted to create a task, they touched the *Aufgaben*-view again although it was already selected. In this application identifying the selected tab is supported by using the same background color for the corresponding action bar (cf. figure 4.1). It seems that more conspicuous clues are needed to make the current position apparent (e.g., bringing the tab to the front by using a three-dimensional effect). Occasionally participants missed a point in the application to start from when the next task of the test was set. Because a tabbed-navigation is used, such a starting point is missing. Apparently, a clear starting point within the application would help the elderly to remember certain sequences of steps to complete a task. When the interface can be reset to this starting point at any time, the elderly could start over again when they lose track or just intend to get to a point of the application they can surely remember.

5.5.2 Language and Wording

Because the *Tagesplaner*-application does not use a single term of a foreign language or with a technical background, the meaning of each term was clear to all test persons. Two participants[1] judged this positively: "I like that not a single English term is used. I often have problems understanding them.". However, though the meaning was clear, some labels and terms were obvious for the participants at first sight. As an example, one test person was looking for a button to close a dialog. She was searching for the term "Schließen" (translated: "Close") instead of "Abbrechen" (translated: "Abort"). Generally, it was conspicuous that the elderly more often scanned the screen for certain terms to go on with a task. When they did not find this specific term on the screen, some participants started rashly trying out other buttons on the current view instead of making well considered decisions (e.g., navigating to another view searching for a solution). In this way, they were often confused about the action called.

5.5.3 Icons

Combining icons with labels where possible (cf. MMD 2), was important for the test persons as well. The meaning of many symbols is not clear when their labels are missing. Additionally, providing buttons with labels make them more self-descriptive. Thus, the labeling of buttons, tabs and text fields was essential to 11 out of 12 persons. As an example, the "Show Details"-icon (cf. figure 4.1) is not combined with a label. Participants often asked: "Can I click on this?" or "Where do I get the details of this appointment?". In this case, a simple

[1] All participants were Germans.

button called “Show More Details” may be more effective, even if it is not accompanied by an icon.

5.5.4 Interaction

Concerning interactive methods, within the *Tagesplaner*-application the textual input with the standard Google Android keyboard was the most problematic one. Nearly every participant (9 out of 12) rated the buttons on the keyboard as clearly too small. Typing errors occurred very often and inserting text required often much concentration and time. One participant said: “Typing with the fingertips having arthrosis is very hard for me.”. But also test persons who could deal with the keyboard quite well would prefer a larger keyboard. Additionally, some participants had problems in reading the letters on the keys as they were too small as well. Three test persons, moreover, could not find the space bar on the keyboard, since it is displayed as large gray area at the bottom of the screen and therefore was not interpreted as a button. Furthermore, understanding the functioning of shift key was not clear as well. Some thought it has to be pressed while touching the letter as known from hardware keyboards. More irritating for inexperienced participants, however, was the different labeling of the letters on the keyboard. At the beginning of a sentence the letters are displayed in uppercase (as known from hardware keyboards), lowercase otherwise. This connection was not obvious to several test persons. Regarding the keyboard layout, 11 participants had no problems finding the keys on the QWERTZ-layout[2]. Only one person preferred an alphabetically ordered keyboard since she had no experiences in using the QWERTZ-layout.

Concerning the standard Android widgets to select a date or time, figure 4.9 shows that these consist of two or three columns containing three rows each. The center row, emphasized by the darker font color, indicates the selected date or time. The values within each column can be scrolled separately up or down to select a previous or later date or time. This input method was difficult to use for 9 out of 12 participants. Selecting the desired date or time was problematic, since scrolling the values up and down required accurate interaction with the element. Frequently, the intended scrolling gesture was not detected when the test person started the gesture exactly on a value or it was scrolled too far when the gesture was detected but executed too fast. Apart from that, one of the buttons below the widget

[2]Since this study was conducted with German participants, the country-related QWERTZ-layout was used instead of QWERTY.

("Abbrechen" or "Fertig") was pressed by mistake very often, due to the little space left between the widget and these buttons. Thus, these problems were experienced as very frustrating and most of the test persons became impatient. On some occasions, participants had difficulties understanding the handling of the widget. Instead of the center row, the first or last row was used to insert the desired date or time. Hence, the darker font color of the center row did not emphasize its function clear enough (cf. figure 5.1).

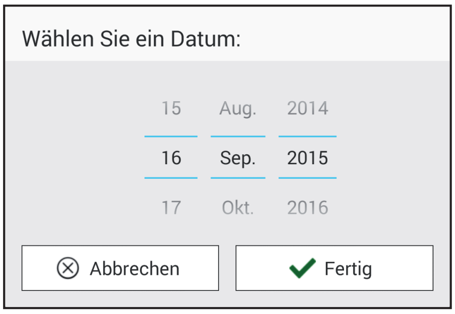

Figure 5.1: Instead of the Center Row Several Participants Set the Desired Date into the First or Last Row.

Furthermore, the participants were asked whether they preferred the scrolling gesture or the "Up"- and "Down"-buttons to move items within lists. Since guideline INT 1.5 advises against using scrolling gestures, it was expected that the test persons favor the "Up"- and "Down"-buttons. In fact, 11 out of 12 test persons preferred the scrolling gesture no matter if they have had experiences in using touch devices or not. Participants who learned the gesture during the test found it more intuitive than the buttons. Others could transfer the gesture from the similar scrolling action on a PC using the mouse wheel. Only two test participants favored the "Up"- and "Down"-buttons, since in this way the list can be scrolled item by item. Because this type of scrolling was slower and more predictable, these test persons could control the action better.

5.5.5 User Support and Training

Previous knowledge of the participants concerning touch devices as well as computers in general, highly influenced the amount of support needed to complete a task of the test. Nearly all participants (10 out of 12) already have had "good" or "very good" computer skills (e.g., E-Mail and Office). In addition, 9 persons have had experience in using tablets or smartphones, which directly influenced the amount of time they needed to complete the test. The average time of the experienced test persons was approximately 40 minutes, the inexperienced took 60 minutes. Moreover, the participants having smartphone or tablet skills needed significantly less support concerning the navigation, data entry, finding functions and remembering them. The participants needing more support, however, did not judge the occurring problems as unsolvable or an obstacle. For these persons it was rather important to have more time for practicing and to calmly try out the applications functions on their own without being observed. Hence, although the application scenario was judged to be simple and the interface uncluttered, training and personal support is often inevitable for the elderly.

5.5.6 Conclusion

Overall, the feedback of the participant was positively except for the lack of time needed to get familiar with the application. Most participants found the application to be self-explanatory although they did not find each function intuitively. Understanding the information structure (i.e., where to find a function or item) needs more training than provided within this study. Concerning layout and design of the application, the test persons had less improvement suggestions than anticipated. Texts and buttons were displayed in an appropriate size. Hence, they were discernible, legible and could be targeted accurately. The tabbed navigation was easy to understand on one hand, on the other hand a more conspicuous indication is needed to discern the currently selected tab. Additionally, the simple language and labeling of buttons was supportive for the elderly in finding their way through the application. However, an obstacle was the use of the tested default Google Android keyboard and widgets. Displaying a full QWERTY keyboard on a 7-inch device in portrait mode is considered too small and is not recommended. Moreover, the usage of the date- and time-picker widgets provided by Android (cf. section 4.2.5) should be discontinued (in Android 5.0 these widgets are redesigned and therefore require future testing). Scrolling in these widgets (e.g., to change the month) on a small area requires too much concentration and manual dexterity. Inserting a date or time using a (software) numerical key pad as proposed in guideline INT 2.5 may be more suitable in this case. Thus, those interface elements which were consciously designed by putting guidelines into practice (e.g., buttons, navigation menu etc.) indeed supported the elderly in using the application.

5.6 Summary

In this chapter the development process of a usability study is described to test the *Tagesplaner*-application. Since age-related physical and cognitive impairments influence how the elderly behave in a test situation, guidelines provided by Silva and Nunes [2010] are taken into consideration to support the test persons and avoid overexerting. Many of these guidelines indeed were supportive for all participants. However, some guidelines were very important for individuals, although they were not necessary for the majority. For example, the test persons were informed about the aim of the study, the single steps of the test and the fact that it is the application to be tested and not the person him or herself. Though this information was not necessary for each participant, it was helpful for those who were less confident about the situation and being observed.

The study itself showed, that applying the design guidelines from chapter 3 indeed supported the elderly in using the application. Major problems only occurred when functionality had to be used which was not considering these guidelines (i.e., Standard Google Android keyboard and widgets).

Moreover, the chosen test scenarios (cf. section 5.3) supported the test persons in imagining using the application in every day life, even those who said “I would not use this application. I prefer my ordinary organizer.”. A guideline which was more difficult to fulfill was keeping the test short in time. Silva and Nunes [2010] propose to limit each test to around 20 minutes. Since the participants were different in their previous knowledge, the time needed to complete the tasks varied from person to person between 20 and 60 minutes. Additionally, most participants would rather try out the application by themselves in a more comfortable situation without being observed. As a consequence, when getting the application known without pressure a more differentiated opinion can be formed. Thus, finding a test situation in which the participant feels comfortable on the one hand, and gives the opportunity for the interviewer to observe and act supportive if needed on the other hand is a difficult problem.

As mentioned in section 5.4 the participants recruited for this study have been well-educated and mostly in a good physical condition. To get a deeper insight in how elderly people with less physical or cognitive abilities are able to use this application, a larger variety of participants is needed.

6 Conclusion

Developing tablet-applications for the elderly requires a basic understanding of common age-related cognitive and physical impairments. As such impairments influence the way older people use tablet-applications, capabilities and characteristics of the elderly have to be taken into consideration more consciously within the design and development process. Different proposals of design recommendations concerning older adults are published in recent literature. However, these either do not discuss certain touch related issues in detail (e.g., interaction design) or are expressed and derived imprecisely. The aim of this thesis was to provide a comprehensive compilation of usability guidelines for the elderly derived from literature which additionally should make its reason and significance clear to designers and developers of tablet-applications.

Therefore, this thesis first briefly summarized fundamental issues like general usability aspects, characteristics of aging as well as benefits of using touch devices and appropriate applications with focus on older people (cf. chapter 2). All in all, within this work 58 guidelines derived from literature were collected and discussed in detail (cf. chapter 3). In order to point out the medical and psychological background of these guidelines, literature concerning interface design for the elderly was collected and analyzed. These guidelines cover different design aspects and therefore were grouped into seven distinct categories: *Design* [DES], *Layout* [LAY], *Language and Wording* [LAN], *Icons, Graphics and Multimedia* [MMD], *Interaction* [INT], *User Support and Training* [SUP] and *Personalizing Application Interfaces* [PER]. Moreover, they can be applied to a wide range of application scenarios and cover a large amount of use cases. Thus, the realization of every single guideline is hardly ever necessary. In fact, mostly due to limited development resources it is important to be aware about cost-benefit factors of each guideline brought into practice.

In order to develop an exemplary tablet-application suited for older people, several of these guidelines were taken into consideration. Chapter 4 described which guidelines were applied and how they could be realized. In order to cover a suitable use case, an application to plan and review events of a day was developed which combines diary- and calendar-like functions. Due to the limited screen space of the target device (i.e., a 7-inch display) in combination with relative large font sizes and buttons (as proposed in the guidelines), displaying sufficient information was challenging. As an example, shorter but more imprecise headings had to be found when an appropriate font size had to be used at the same time. Hence, the proper screen size of the device itself influences the usability of an application as well.

Finally, a usability test was conducted to proof whether the realization of the guidelines actually influenced the way the elderly participants could use the application positively (cf. chapter 5). This study showed, that the participants had less problems in using the application concerning those design aspects which were realized considering the proposed guidelines. As an example, the suggested and applied font size was appropriate for nearly all test persons whereas using the standard Google Android Widgets (e.g., date- and time-picker) was very problematic. Altogether, the participants feedback was mainly positive although most of them wished more time to get used to the application. This indicates that the proposed usability guidelines actually help designers and developers producing tablet-applications for the elderly.

7 Future Work

Concerning the usability test, future work should focus on a wider range of participants. More test persons with different age-related impairments or educational level should be interviewed in order to investigate further improvements for this exemplary application. As within this study the usability of standard Google Android widgets was superficially tested, another research opportunity would be to examine styleguides of common operating systems of mobile touch devices (e.g., Google Android or Apple iOS). Furthermore, since some guidelines are derived from studies which base on outdated technical standards, these findings may have to be revised. For example, [Darroch et al., 2005] analyzed the appropriateness of font sizes for the elderly on devices with a screen-resolution of 640 x 480 pixels, while the latest tablets can reach a screen resolution up to 2048 x 1536 pixels (e.g., Apple iPad [Apple Inc., 2015]). Additionally, it would be beneficial to find the optimal screen size of tablets for the elderly. Since some of the participants (taking part at this study) who already owned a tablet preferred a 10-inch display, it can be assumed that smaller screen sizes are less suitable for the elderly. However, this has to be proven in further investigations.

A Formula to Calculate Color Contrast

With the following formula the contrast ratio can be calculated [W3C, 2008]:

L_1, L_2: relative Luminance (in sRGB color space) of the lighter (L_1) and darker (L_2) of the colors.

$$ContrastRatio = \frac{L_1 + 0,05}{L_2 + 0,05} \tag{A.1}$$

The relative luminance L is calculated by:

$$L = 0,2126 * R + 0,7152 * G + 0,0722 * B \tag{A.2}$$

with R, G and $B \in C$

$$C = \begin{cases} \frac{C_{sRGB}}{12,92} & \text{if } C_{sRGB} \leq 0,02928 \\ (\frac{C_{sRGB}+0,055}{1,055})^{2,4} & \text{else} \end{cases} \tag{A.3}$$

The values C_{sRGB} (i.e. R_{sRGB}, G_{sRGB} and B_{sRGB}) are calculated by:

$$C_{sRGB} = \frac{C_{8Bit}}{255} \tag{A.4}$$

Where C_{8Bit} is the 8 bit value of the red, green or blue color channel.

B Study Scenarios

The following two scenarios were used to ensure that each test person gets the same level of experience and knows the same amount of functionality.

Szenario 1

(erwartete Dauer: ___________ // tatsächliche Dauer: __________)

- Sie erfahren, dass übermorgen eine Bekannte Geburtstag hat und eine Geburtstagsfeier für übermorgen geplant hat.
  Erstellen Sie einen Termin:

Titel	Geburtstagsfeier
Datum	<übermorgen>
Zeit	14:00 – 19:00
Ort	Ulm

  Rufen Sie die Detailansicht dieses Termins auf, überprüfen Sie die Daten und Schließen Sie diese wieder.

- Sie möchten auch noch ein Geschenk organisieren, haben jedoch noch keine Idee und möchten Frau Müller nach einer Geschenkidee fragen.
  Rufen Sie Frau Müller an.
- Eine der Geschenkideen von Frau Müller war eine Flasche Wein. Sie möchten sich diese Idee notieren.
  Erstellen Sie eine Notiz:

Titel	Geschenkidee von Frau Müller
Beschreibung	Frau Müller hat eine Flasche Wein vorgeschlagen.

- Sie möchten die Flasche Wein noch heute besorgen und beschließen heute noch einkaufen zu gehen.
  Erstellen Sie eine Aufgabe:

Titel	Wein kaufen
Datum	<heute>
Zeit	keine
Wiederholung	keine

- Nehmen wir an Sie haben den Wein nun gekauft.
  Markieren Sie die Aufgabe „Wein kaufen“ als erledigt.
- Ihnen wurde mitgeteilt, dass die Geburtstagsfeier auf den nächsten Tag verschoben hat.
  Ändern Sie das Datum des Termins „Geburtstagsfeier“.

Szenario 2

(erwartete Dauer: ___________ // tatsächliche Dauer: __________)

- Eine bereits erstellte Aufgabe für heute lautet: „Ausflug nach Stuttgart organisieren“. Dies möchten Sie nun erledigen.
- Der Ausflug ist für nächste Woche Freitag geplant. Erstellen Sie einen Termin:

Titel	Ausflug nach Stuttgart
Datum	<nächsten Freitag>
Zeit	10:00 – 16:00
Ort	Stuttgart

- Sie möchten Frau Müller dazu einladen mitzukommen. Rufen Sie Frau Müller an.
- Nehmen wir an, Frau Müller hat zugesagt. Sie schlägt vor ein Baden-Württemberg-Ticket zu kaufen, da das die günstigste Fahrkarte ist. Das möchten Sie sich notieren. Erstellen Sie eine Notiz:

Titel	Fahrkarte
Beschreibung	Baden-Württemberg-Ticket

- Nun möchten Sie die Fahrkarte heute noch am Fahrkartenschalter kaufen. Erstellen Sie eine Aufgabe:

Titel	Fahrkarte kaufen
Datum	<heute>
Zeit	keine
Wiederholung	keine

- Der Ausflug ist nun organisiert. Markieren Sie die Aufgabe „Ausflug nach Stuttgart organisieren“ als „erledigt“.

C Interview

The following pages contain the questions of the interview to investigate the opinions and experiences the participants made using the *Tagesplaner*-application.

Fragebogen

Datum: ___________________________________

Beginn: ___________________

Ende: ___________________

Persönliches

1. Alter
2. Geschlecht
3. Einschränkungen in Wahrnehmung? z.B. Rot-grün-Blindheit

Vorkenntnisse – Welches **Vorwissen** hat die Person im Umgang mit Tablets und Apps?

1. Haben Sie überhaupt schon mal einen Tablet-Computer genutzt?

    - Wenn ja → Besitzen Sie selbst einen Tablet-Computer und nutzen diesen auch?

        - Wenn Ja → Wofür nutzen Sie Ihr Tablet hauptsächlich?

        - Wenn Ja → Wie gut kommen Sie mit ihrem Tablet zurecht?
          (Gibt es Probleme, auf die Sie häufig stoßen, wenn Sie Tablet-Anwendungen nutzen?)

Allgemein

1. Erster Eindruck – Wie sind Sie zurechtgekommen?
   Was hat Ihnen gut gefallen? Was nicht so gut?

2. Gab es Aufgaben, die Sie weniger gut oder gar nicht **lösen** konnten? Aufgaben wo Sie länger nachdenken mussten.

Design & Layout

1. Empfanden Sie die **Größe** der Elemente (Texte, Schaltflächen usw.) als Angemessen?
   Vllt. sogar übertrieben groß?

   - (text size) **Schriftgröße** angemessen?

   - Gab es Elemente (Bilder, Texte usw.), die Sie nicht eindeutig **erkennen** konnten? Z.B. zu klein waren oder zu wenig von anderen Elementen abgehoben haben?

   - (button size) Hatten Sie das Gefühl dass die Schaltflächen/Knöpfe/Buttons immer gut treffen zu können?

     - Wenn nein → Welche nicht?

     - Wenn nein → Hätten Sie sich eine andere Form von Rückmeldung bei der Bildschirmberührung gewünscht? (feedback)

2. (information structure) Gab es stets **genügend Hinweise** um eine Aufgabe lösen zu können? Selbsterklärend?

3. (navigation) Gab es Situationen in denen Sie den **Überblick** verloren haben bzw. sich nicht mehr orientieren konnten?

Sprache und Konsistenz

1. (consistency) Gab es Situationen in denen Sie Funktionen/Schaltflächen vermisst haben?

2. (language and wording) War die **Beschriftung und Symbole** der Buttons immer eindeutig?

3. Gab es Situationen in denen Sie nicht die Funktion aufgerufen haben, die Sie eigentlich erreichen wollten? Aus versehen auf den falschen Button geklickt?

Interaktion

1. (**scrolling**) Die dargestellten Listeneinträge können durch eine Schaltfläche oder durch eine Geste bewegt werden. Welche der beiden Optionen haben Sie hauptsächlich benutzt?

2. (data input) Würden Sie eine andere **Eingabemethode** für Text bevorzugen (Computertastatur)?

Hilfe

1. Hatten Sie das Gefühl die Aufgaben einfach und ohne **fremde Hilfe** lösen zu können?

2. Wie oft hatten Sie während der Benutzung das Gefühl Hilfe zu benötigen?
   Wo gab es **Unklarheiten**?

3. Wussten Sie stets, wie und wo Sie die **Hilfe aufrufen** konnten, wenn Sie Hilfe benötigt haben oder hätten?

Personalisierung

1. Hätten Sie die Anwendung gerne mehr auf Ihre persönlichen Bedürfnisse eingestellt (z.B. Textgröße, Buttongröße, Schriftart, Hintergrundfarbe …) ?

2. Empfanden Sie die zur Verfügung stehenden **Einstellungsmöglichkeiten** als sinnvoll?

Fazit

1. **Alltagstauglichkeit** – Würden Sie die Anwendung im Alltag benutzen wollen?

2. **Verbesserungsvorschläge** – Haben Sie allgemeine Vorschläge, die die Benutzung der Anwendung für Sie erleichtern würden?

- Wenn Einschränkungen → Konnten Sie die Anwendungen trotz Ihrer Einschränkung gut bedienen?

D Evaluation

The following table contains a brief overview of the study evaluation.

			VORKENNTNISSE						INTERACTION			GRÖẞE		LAYOUT		ICONS
	Geschlecht	Alter	Vorkenntnisse	Tablet-Besitz	Nutzung	Sonstige Vorkenntnisse	Dauer (min)	benötigte Hilfe	Probleme mit Keyboard?	Scrolling genutzt	Probleme mit Time/Date Widget?	Meinung über Textgröße	Meinung über Buttongröße	App selbsterklärend?	Überblick verloren?	Icons ohne Label verständlich?
1	w	74	ja (gut)	ja	Mails, Google, QR-Code	gute Computerkenntnisse	45	mittel	ja (zu klein)	ja	ja	gut	gut	nein Hilfe wichtig	nein deutlich angezeigt, orientierung immer da	nein
2	w	70	ja (sehr gut)	nein		iPhone (Whatsapp, Mails, Internet)	45	kaum	ja (zu klein)	ja	ja	gut	gut	ja	nein	nein
3	w	73	nein	nein		kaum Computerkenntnisse	75	viel	nein (aber trotzdem zu klein)	ja	ja	gut	gut	ja (mit Übung)	nein	nein
4	w	74	ja (sehr gering)	nein		gute Computerkenntnisse (Office)	60	viel	ja (zu klein)	ja	ja	größer	größer	ja	nein	nein
5	m	64	ja (sehr gut)	ja	Navi, News, Streaming	gute Computerkenntnisse	30	kaum	nein	ja	nein	gut (eher kleiner)	gut	ja	nicht eindeutig, wann tab schon ausgewählt ist. Ausgangspunkt vermisst	nein (symbol unwichtiger als label)
6	m	78	ja (sehr gut)	ja	Mail, Wetter, Zeitung, Bahn	gute Computerkenntnisse	45	wenig	ja (zu klein)	beides	ja	gut	gut	ja	nicht eindeutig, wann tab schon ausgewählt ist. Ausgangspunkt vermisst	nein
7	w	73	nein	nein		gute Computerkenntnisse	45	viel	ja (zu klein)	ja	ja	gut	gut	nein Hilfe wichtig	nein	nein
8	m	67	ja (sehr gut)	ja	Mail, Internet, Kalender, Whatsapp, Monitoring	Smartphone(Mail, Internet, Kalender, Messaging, Monitoring)	25	kaum	nein	ja	nein	gut	gut	ja	nein	nein
9	w	81	ja (gut)	ja	Mail, Wetter, Internet	Computerkenntnisse	45	viel	ja (zu klein)	ja	ja	größer	größer	nein Hilfe wichtig	nein	nein
10	w	68	nein	nein		KEINE Computerkenntnisse, KEIN Smartphone	60	viel	ja (zu klein, keine QWERTY erfahrung)	ja	ja	gut (eher größer)	größer	nein Hilfe wichtig	ja – überfordert mit situation	nein
11	m	64	ja (sehr gut)	nein		iPhone(Mail, Tel, Navi, Wetter, Bahn)	30	kaum	nein	nein	nein	gut	gut	ja	nein	
12	w	76	ja(gut)	nein		gute Computerkenntnisse, Smartphone(Mail, Messaging, Bahn, Nachrichten, Kamera, Wetter)	50	kaum	ja (zu klein)	ja	ja	gut	gut	ja	nein	nein

Durchschnittsalter: 71,8333

Durchschnittliche Zeit (ohne Vorkenntnisse):	60
Durchschn. Zeit (mit Vorkenntnisse):	39,375
Durchschn. Zeit (insgesamt):	46,25

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Erklärung

Hiermit erkläre ich, dass ich die Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe.

Ulm, den ....

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