Guideline to Support Human Aspects in Mobile eHealth Applications: Version 1

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1 Introduction

Health related mobile applications are known as ***eHealth apps***. Such eHealth app usage is rapidly increasing with a large number of new apps being developed and deployed annually. These apps make people more aware of their health, help in self-management of critical illnesses, provide home-based disease management, and help with personalized care through sensing and interaction. However, the users of eHealth apps are naturally diverse in terms of their ***Human aspects***, e.g., their emotional reactions to the eHealth apps, varying language proficiency, socioeconomic status, educational level, cognitive style, physical and mental challenges, gender, age, personality and many more. Unfortunately, many eHealth apps do not take these user differences sufficiently into account, making them ineffective or even unusable.

Consider a representative example eHealth app '*SleepNea*', which helps clinicians to continuously monitor a sleep apnea patient's breathing and oxygen from a remote location. In the app, data needs to be updated continuously to provide real-time information. This information can be updated immediately or batch uploaded after an interval. Dealing with sensor data and handling network issues are technical domain concerns. However, the design and work process of the app must deeply appreciate and address the human aspects of users, e.g., differing physical and mental challenges. For example, app usage, data exchange through sensors, and use of the extra device should not affect the day-to-day lives of the patients, their families and friends, as well as clinicians and community workers. It also must address the technological proficiency and acceptance by different users with different cultures, languages, and ages than the app developers.

The development of '*SleepNea*' app also should factor in differing emotional – both positive and negative — reactions to the app, e.g., up-to-date feedback and suggestion is potentially positive but being continuously monitored potentially negative. The accessibility of the solutions needs to be considered for people with physical tremors, poor eyesight, being wheelchair bound, or with cognitive decline. The usability of this app

for a group of people should also address the varied needs, incorporating the use of sensors and modified smartphone interface, accommodating different ages, genders, cultures and languages of users, including appropriate use of text, colors and symbols. This is particularly important as one-quarter of the elderly in Australia are non-native English speakers and the majority are women, but by far, the majority of software developers are 20-something-year-old English-speaking men, the same as in the United States and dominant English-speaking countries. eHealth app users' personality differences may be important, e.g., those who want flexible dialogue with doctors compared to those needing directive suggestions from the app itself. The failure of developers to incorporate such human aspects in their eHealth apps can result in the apps that are unsuitable for whom it is designed for by introducing confusing, possibly unsettling and invasive, and even potentially dangerous technology.

Therefore, in this report, we propose a more integrated approach for eHealth app development and usage that addresses the human aspects of its users in the form of improved actionable guidelines, workflow framework, best practice examples, and evaluation techniques. We have categorized the identified human aspects, their impacts, and best practice examples into four categories to produce the proposed guidelines – (i) Diverse User Issues (ii) Usability (iii) Accessibility (iv) Reliability and Validity.

Our proposed guidelines for diverse user issues cover human aspects in eHealth apps related to age, gender, culture, language, cognitive style, working conditions, socioeconomic diversity, technological acceptance challenges, vulnerable users, marginalized people, and health literacy. We also present user experience guidelines under diverse user issues. This is because factors such as presentation, functionality, performance, and interactive behavior are closely associated with catering to users' diverse needs and preferences.

Our proposed usability guidelines cover issues related to app design, navigation, and assistance, while our accessibility guidelines cover issues related to app content, input-output, functionality, and assistance. Similarly, our proposed reliability and validity guidelines cover decryption and disclosure, documentation and source, advertisement and policies, updates and changes, interoperability, safety, policy statements, and data privacy for eHealth apps.

We have limited the scope of the proposed 'new and enhanced' set of guidelines to the key human aspects in eHealth apps only, which emerged from stakeholders' concerns, our evaluations of existing guidelines and checklists, and addressing their identified gaps. The guidelines also provide practical examples to illustrate how some key human aspects can be addressed and what app developers need to do to produce more human centric eHealth apps.

2 Guidelines for Diverse User Issues

eHealth apps must address issues related to their diverse user base. We define ***Diverse User Issues*** as the app's ability to be effectively used by a wide range of users, including those with varying language proficiency, socioeconomic status, educational level, cognitive style, physical and mental challenges, gender, age, personality, and many more. This also includes catering to various user groups' needs and requirements by integrating different technologies, methods, and practices. We proposed our key guidelines for eHealth apps that aim to improve diverse user issues below, dividing them into nine sections:

2.1 User Age

eHealth app users can be of different ages. Some users may be elderly and have varying needs and preferences that differ from those of younger users and app developers. For elderly users, eHealth apps should feature a user-friendly interface incorporating larger font sizes and simplified navigation, making the app more effective and easier to use. For example, a telehealth and telemedicine app could feature audio prompts and reminders to assist them with medication schedules or appointment reminders.

Then, for the younger users, the same app could include more advanced features and interactive components, such as chatbots, to provide more personalized experience. This could include asking questions and receiving instant responses. Social media platform integration within eHealth apps is also recommended for younger users. This helps connect them with others having similar health concerns or interests.

Identifying users' age ranges and distinguishing them into different groups to offer different app interfaces/features can be accomplished during the app's onboarding process. The app should explain to users why their age range information is needed, how it will be used and protected. Additionally, eHealth apps should automatically update the user age range over time and suggest appropriate health actions based on the current information (age) to ensure that the users receive personalized recommendations that reflect their changing health needs. To achieve this, machine learning algorithms can be beneficial for app developers.

2.2 Gender Identity

eHealth apps should consider gender-based user preferences and needs, and feature information specific to user genders, and be gender-inclusive. It is recommended to allow users to self-identify their gender. This can mitigate threats related to app developers' unconscious biases that may lead to gender-based assumptions about users' health needs.

eHealth apps should not be designed assuming all users are identified as male or female. Then, eHealth apps should avoid using gendered language that excludes users based on gender identity, including those who identify as non-binary or transgender. Therefore, instead of using gender-specific pronouns such as 'he' or 'she', it is recommended to use gender-neutral language such as 'they' or 'the user' during documentation and information presentations.

Furthermore, app developers should conduct app testing and evaluation with individuals of different genders before launching the app. For instance, user testing might reveal that the app's language, imagery, or features unintentionally exclude or misrepresent some gender identities. The developers can then correct those and make the app truly inclusive and relevant to all gendered users.

2.3 Language

eHealth app developers should prioritize supporting multiple languages in key app features. For example, the app's symptom tracker, medication reminder, or appointment scheduler should be available in multiple languages. Additionally, eHealth apps should allow users to set their preferred language during onboarding and easily switch between languages anytime during app usage. This effectively supports linguistic diversity within apps.

eHealth app should also use simple language and avoid technical jargon or medical terms as much as possible to communicate health information clearly and easily. For instance, an eHealth app designed to manage vaccinations for children should use plain terms like 'vaccination' or 'shot' instead of technical terms like 'immunization'. Furthermore, the app should always explain any medical or technical terms used to help all users better understand the information presented. For the running example, this includes providing information about why a vaccine is important, how it can protect against specific diseases, and any potential risks and benefits associated with it.

2.4 Culture

eHealth apps should be designed with cultural diversity as a first-class citizen, including users' preferences, values, beliefs, and norms of different communities in app design and work process. The app should provide information and resources that are culturally sensitive and relevant to its users' cultural backgrounds. For example, eHealth app designed to manage diabetes through nutrition and food tracking should consider its users' beliefs and community practices. This app should adhere commonly eaten foods and dietary restrictions during recommendations, such as vegetarian or halal options for users who adhere to religious or ethical dietary restrictions app users. The app should also adjust its nutrition guidance during cultural events like Christmas and Eids while adhering to diabetes management goals. Then, the apps should avoid using cultural stereotypes or assumptions that may offend or exclude users based on their cultural background.

It is also recommended to build app developer team with diverse cultural backgrounds and experiences. This inherently brings various cultural perspectives, i.e., cultural sensitivity and demand to eHealth app's design and development. Furthermore, testing and evaluating eHealth apps with individuals from diverse cultural backgrounds can help to identify any unintentional cultural biases or assumptions in the developed app's and act according to address them.

2.5 Cognitive Style and Working Conditions

eHealth apps should aim to minimize cognitive load in app usage, especially during task completion and following recommendations. For instance, an eHealth app designed to address mental health concerns should consider that some users may struggle with managing anxiety or depression. In such cases, reducing cognitive load in app usage can help users better focus on their issues. Furthermore, accommodating different cognitive styles and working conditions of users can greatly enhance app effectiveness. It is also recommended that eHealth apps follow a dynamic work process adaptable to users' changing needs. For example, mental health management app could offer visual cues to guide users through breathing exercises to alleviate anxiety when it observes related symptoms among its user. Testing the app with a diverse user group is critical to identify points where adjustments are needed to reduce cognitive load and accommodate different cognitive styles.

eHealth apps should accommodate the diverse working conditions of their target users. The apps should also ensure that users their users can access all information they need, regardless of their working conditions. This may involve tailoring app features and content to specific contexts. For example, the mental health app, when used by doctors, could provide clinical guidelines, while the same app, when used by firefighters, could

show resources for addressing mental health issues in emergency response situations. Determining user working conditions dynamically can be challenging, but the modern sensor and AI-based technology help automate this process. For example, a mental health app could use the microphone sensor to monitor ambient noise levels, a fitness app could use the GPS sensor to determine if the user is exercising outdoors, a nutrition app could analyze the time of day to recommend meal plans or a sleep tracking app could use the accelerometer sensors in a user's smartphone to identify if the user works non-standard hours and provide personalized sleep recommendations.

2.6 Socioeconomic Diversity

eHealth apps should accommodate the socioeconomic status of their users in app design and behavior. This includes users' educational level, living situation, income, occupation, knowledge, and attitudes. For example, an eHealth app designed to help people manage common health concerns like fever, headache and nausea can provide information that is easy to understand and actionable for all, including low socioeconomic groups, such as suggesting low-cost or over-the-counter remedies. This will also be helpful for users needing access to traditional healthcare. Similarly, an eHealth app that provides diabetes management resources can suggest low-cost healthy food options and recommendations for lifestyle changes for those user groups.

Identifying the socioeconomic condition of eHealth app users are challenging. However, partnering with community-based organizations during app design and analyzing user app usage patterns can greatly assist in serving this purpose. Community organizations can also provide valuable insights into the needs and preferences of different groups. They generally work as a trusted source of information and can greatly increase awareness about app services/benefits through a clear value proposition among different user groups, including those who may be hesitant to try services from eHealth apps. Then it is also recommended to test eHealth apps with users from diverse socioeconomic backgrounds to identify potential issues that may impact the app's effectiveness.

2.7 Technological Acceptance Challenges

eHealth apps should operate seamlessly across various devices and operating systems, including different hardware and software versions. For example, a patient monitoring eHealth app must function equally well on devices with diverse screen sizes, such as smartphones and tablets. The app's capabilities must also be optimized for different platforms, such as iOS and Android, with the interface and functionality automatically adjusted.

Then, eHealth app developers should manage the project's budget and schedule throughout the development lifecycle. Agile methodology can be particularly helpful in this context as it emphasizes breaking down the project into smaller sprint phases. Each sprint delivers a working product increment, providing a valuable feedback loop and minimizing risk by addressing technical issues as they arise.

It is recommended that eHealth apps incorporate intelligent systems. For example, the app can use interactive forms or automated tools that guide users through the data collection process step by step. Additionally, app developers should perform compatibility and performance optimization testing while addressing technological acceptance challenges in eHealth apps. This ensures that the app is optimized and meets the user's

needs and expectations. It is also recommended that eHealth apps should be regularly updated. For instance, if new technology enhances a diagnostic feature's accuracy, the development team should integrate it to offer the best possible service. App developers should follow a formal release and update process to do this. The updates must address any identified technical issues and bugs without impacting existing usage/user experience.

2.8 Vulnerable Users, Marginalised People and Health Literacy

eHealth app developers should recognize the unique challenges of vulnerable user groups and marginalized people. They should incorporate features and design elements that address physical, cognitive, and emotional barriers to app usage for those users.

It is also recommended that eHealth app appropriately address health literacy challenges for vulnerable and marginalized user groups. This includes using plain language to communicate health-related information for users with limited health literacy, using culturally appropriate visual aids, and providing relevant information (context) for their health needs. For example, an eHealth app designed for Indigenous communities might include traditional healing practices and remedies, while an app designed for immigrants and refugees might provide information on healthcare access procedures in new locations.

Developers should involve vulnerable and marginalized users in the app development process, including testing and evaluating the app with these user groups to identify relative issues. It is also recommended that app developers collect feedback from these users through app development life cycle to identify areas where their eHealth app may fail to meet user needs. For example, an eHealth app designed for maternal health care may need to account for community practices and beliefs for racial and ethnic minorities, which can only be identified by collecting feedback from them.

2.9 User Experience

eHealth apps should be easy to use, intuitive, straightforward to navigate and offer personalized user experiences to increase engagement and relevance. Complex or confusing features can discourage eHealth app users from adopting it and limit its effectiveness. For example, an excellent eHealth app for fitness tracking should prioritize its core function to track users' daily calorie intake. This can be achieved through a simple, easy-to-use food diary allowing users to log their meals and snacks. It should also contain an extensive food database and nutritional information for each item. The app should support users in scanning barcodes of packaged foods, which automatically inputs the nutritional information into the food diary. Then, it can offer personalization support, such as allowing users to set daily calorie and macronutrient goals and providing personalized feedback to improve nutrition and fitness. The app can also support social aspects, such as connecting with friends and family and offering various challenges and rewards to motivate users to achieve their health goals.

eHealth apps that prioritize interaction and engagement are more likely to be used regularly by their users. Features such as gamification (incorporating game elements into the app), progress tracking, and social sharing can significantly enhance the app's interactivity. For example, an eHealth app that promotes physical activity could provide users with daily step challenges and reward them for hitting their targets. By tracking their progress, such as weight loss, blood pressure, or medication adherence, the app can help users visualize their overall progress and stay motivated to continue using it.

Enabling users to share their progress and achievements with friends and family enhances their engagement with the app. It allows them to feel more involved and accountable toward their health goals while gaining additional support and motivation from their social circle.

It is then recommended that Health apps load quickly and function smoothly without glitches or errors, i.e., they should be optimized to perform well across different devices, settings, and connections. Optimizing app performance involves prioritizing code optimization, multimedia asset optimization, and simplifying the app's functionality and design.

3 Usability Guidelines

eHealth app usability is defined as the simplicity of app usage under specified conditions. We found that the eHealth app usability is an essential measurement criterion to fulfill the app usage objectives satisfactorily and effectively, aiming to provide a greater variety of choices for the users with the following key components:

- **Understandability:** Capabilities of eHealth apps to enable end-users to determine whether the apps are suitable for them, what they can be used for, and how they can be used.
- **Learnability:** Capabilities of eHealth apps to enable end-users to learn basic app functions smoothly, e.g., when users use the app for the first time, how easy it is for them to carry out basic tasks.
- **Memorability, error protection and recovery:** Capabilities of eHealth apps to enable end-users to operate and control the app proficiently. For example, how adeptly do users use the app after they learn its usage? how many errors do users make during their daily app usage, how severe are these, and how easily can users resolve them? how easily can users regain app use proficiency after a period of inactivity?
- **Usefulness and satisfaction:** Capabilities of eHealth apps to fulfill the desire, need, or expectation of end-users, i.e., how eHealth apps assist end-users with their health-related issues and how satisfied they are with the app. This also involves attracting app users in daily usage, e.g., how pleasant it is to use the apps.

In the following sections, we have presented usability guidelines for eHealth apps to make them more human centric, dividing them into three sections: Design, Navigation, and Assistance, based on the key components discussed above.

3.1 App Design

eHealth apps should follow best practice design standards, e.g., reference guidelines for Android Apps or iOS apps. We found that *Layout, Color, Graphics (Screen elements), Text, Fonts, Information and Functionalities* are core elements that fulfill usability design issues in eHealth apps – meaningful presentation and appropriate functionalities.

- ❖ **Layout:** Landscape and portrait orientations of eHealth apps should be adaptable so that the app usability does not differ across devices, users, and use environments. The apps should display all information equally well in landscape and portrait modes, and users should be able to adjust screens that extend beyond the scroll lines easily.

- ❖ **Color:** eHealth app's background, contents, icons, and label should use contrasting colors to assist users in distinguishing different app elements more efficiently. The chosen colors should also be culturally acceptable and account for user issues with visual impairments and color blindness. The recommended contrast ratio for body text is 4.5:1 and 3:1 for larger text such as heading.

- ❖ **Screen Elements:** The elements displayed on the eHealth app screen should indicate whether they are actionable or not through distinct designs. The ideal dimensions for actionable elements are 7-to-10 millimeters long and wide, with proper spacing. All elements on the app screen should serve a purpose, and users should be enabled with selectable elements (options) for data input whenever possible. The front screen should also minimize extraneous text, graphics, and animations.

- ❖ **Text and paragraph:** Text in eHealth apps should use well-known terminologies so all users, including non-medical users, can easily understand the meaning. A distinction between font sizes for headers and paragraph text is necessary, which must comply with platform standards, for example, 17-point text for iOS and 14-scale text for Android paragraphs. The line spacing should also be at least 1.2 times the font's height.

- ❖ **Information:** Grouping of information, also known as clustering or listing, facilitates ease of app use and improves overall eHealth app usability. Hence, eHealth app should avoid presenting information in a paragraph format whenever feasible. App elements and information required for its functionalities should be emphasized and placed above the scrolling line. All key information relevant to the app's intended functions should remain on the screen while it is in use.

3.2 App Navigation

Navigation within the eHealth app should be intuitive and seamless, allowing users to complete their desired tasks effectively. We found that issues within – current state and destination path, actions required to complete tasks, and use of best practice are key factors contribute to improving the usability of navigation in eHealth apps.

- ❖ **State:** eHealth app should provide an effortless method for users to determine their current location within the app. The app should also offer simplest possible navigational path to reach a destination. The app can improve navigation by providing shortcut access to screens and best practice software engineering logic, for example, the temporal locality concept that allows faster access to recently accessed screens and the spatial locality concept that enables direct access to screens closely associated with the current screen.

- ❖ **Simplicity:** Navigation within the eHealth app should employ minimal number of taps, swipes, or screens required for a task and facilitate navigation back to

previous pages through reversible actions. The app should offer simple registering, data entering, recovering, reentering, and storing options, clearly indicating their purpose.

- ❖ **Best practice:** eHealth app menu should adopt best practice standards, for example, located on the top or left side of the screen or associated with a hamburger icon. This ensures that end-users remain familiar with current practices. End-users should also be able to bypass detailed instructions, non-essential product information, and personal data entry that are not required for appropriate app functionalities. Similarly, returning users should bypass registration, onboarding, and walkthrough tutorials.

3.3 User Support

We found that the lack of sufficient technical support and the absence of help features can lead to user dissatisfaction. Hence, eHealth apps should provide their users with adequate technical support and troubleshooting assistance. A proper help section, feedback during app use issues, walk-through materials, features customization assistance, notifications for crucial events such as abnormal health conditions, reminders and alarms as per user choice play key roles in improving eHealth app usability assistance related issues.

- ❖ **Help Sections and Communication:** The eHealth app must include a comprehensive but compact help section to aid end-users, including (i) informational links for complex issues; (ii) pop-ups for suggestions, taxonomies, and definitions, (iii) step-by-step guides for technical issues, error messages, and app usage, (iv) charts, graphics, or videos instead of text-based descriptions and discussions for app functions. All assistance-related communications should be clearly and succinctly conveyed in a language easily understandable by all users, regardless of their community, positions, and conditions.

- ❖ **Notifications:** It is essential to notify eHealth app users about key events or crucial changes within the app on time, e.g., when storage capacity or battery is running low, permanent data deletion is needed, registration is necessary, feedback is received, or an error occurs. These notifications should be displayed consistently under best practices standards, such as near input fields or in the top or side pane of the app. Non-urgent notifications should not obstruct app operation or be disruptive. For example, notifications about app updates or information for new app features or services are important, however, they do not require immediate attention and can be deferred or ignored without affecting the critical app operation. To ensure end-users are aware of reminders and alarms, they should be designed to use redundant signals, and users should be required to acknowledge them before proceeding to other tasks within the app. Additionally, end-users should also be able to customize notifications for different events based on their preferred setting options.

- ❖ **App requirements:** eHealth app users should know the minimum system requirements for app use during installation or setup, including information about password requirements, data entry, storage space, and operating system updates. Subsequently, all notifications, updates, alerts, and reminders should stay within the previously established requirements.

4 Accessibility Guidelines

Accessibility in eHealth apps is defined as the degree to which the apps can be used equally by people with and without disabilities. This includes users' ability to effectively access app contents and features irrespective of their conditions, such as physical tremors, poor eyesight, being wheelchair-bound, cognitive decline, context-specific impairments, or users with no medical issues. It also aims to improve user engagement with apps with the following key components:

- **Perceivable:** eHealth apps' capabilities to appropriately perceive app content and information for their end-users, regardless of their conditions. For instance, the perceivable characteristic of eHealth app accessibility enables individuals with vision impairment utilizing screen readers to access and benefit from the app features and content, while users who are deaf or have hearing impairments can view video captions to get the information.

- **Operable:** eHealth capabilities to enable end-users to operate and interact with the app effectively, regardless of their physical or cognitive abilities. For instance, operable characteristic of eHealth app accessibility ensures appropriate input and output mechanisms other than graphical interfaces for users with hand deformities to interact and operate apps with ease. Overall, it ensures seamless and user-friendly experience to all users, irrespective of their physical or cognitive conditions.

- **Understandable:** eHealth app capabilities to enable end-users to understand apps' functions, including information, feature set, and user interface operations, clearly and consciously. This characteristic is crucial because it ensures all users use the app effectively through proper understanding, ultimately improving their health outcomes.

- **Robust:** eHealth app capabilities to ensure end-users can interpret information correctly and robustly through assistive technologies. This includes app content being accurate and error-free, it (app) does not put end-users at risk at any time, and avails proper support when needed for differing users with diverse physical and cognitive abilities.

In the following sections, we have presented accessibility guidelines for eHealth apps to make them more human centric, dividing them into two sections: Content and I/O, and Functionality and assistance, based on the key components discussed above.

4.1 App Content and Input-Output

eHealth apps should facilitate accessible content and various input-output mechanisms for all users, regardless of any physical or cognitive limitations they may or may not have. We found that addressing accessibility issues related to content and input-output in eHealth apps can be accomplished by providing alternative input methods and output choices, adjusting presentation styles, color schemes, font choices, and proper component labeling.

- **Format:** eHealth app components should be consistent throughout the app. Consistency helps users understand the app's operation and reduces the cognitive load

on users. Then, app features accessibility should not be affected by their content format. All content should be adaptable and accessible to all users, regardless of their physical or physiological limitations. This is particularly important for users who mount their devices to a fixed orientation, such as in the arm of a wheelchair, or who have difficulty rotating their device due to limited motor skills and want to access some app content. This is also true for alternative outputs. For example, text alternatives and sign language in place of audio, captions for video content for users with deaf or hard of hearing, and audio descriptions of images for visually impaired users to convey the identical content meaning enhance overall eHealth app accessibility.

- **Standard:** eHealth app components should adhere to best practice standards, especially for the input, presenting information, elements shape, size and visual location conveying relationships among them. Default settings should accommodate common patterns and standards, such as auto-updates runs in parallel with other content, touch targets size be at least 44dp×44dp, actionable elements support different input modes, facilitate one-handed use, and auto-complete standard inputs such as name and email. Limiting auto-interaction should only be done when essential or to ensure the app security.

- **Hardware:** Device hardware should not impact eHealth app operation or content meaning. For example, apps that adjust their data usage, processing power, and displays to accommodate different sensors, screen sizes, and hardware should not affect app operational functionalities to ensure proper accessibility.

- **Preferences:** Users should be able to choose and adjust their input-output preferences while installing apps. Additionally, they should be able to switch between different options as needed. This flexibility is needed as users' needs and preferences may change over time, or circumstances may require different configurations.

  eHealth app users should also be able to adjust the presentation style, foreground, background colors, and contrast ratio to meet their needs. It is recommended to enable users to resize text up to 200 percent in a way that does not require them to scroll horizontally to read a line of text on a full-screen window or bypass a block of content.

- **Validation:** eHealth app users should be able to track and validate their inputs through responsive design and actions. For example, voice commands may produce inexact results, so users should be able to validate and correct them. Users should also be able to adjust time limits without unexpected changes in the app content or context and suppress or postpone interruptions if needed.

4.2 App Functionality and Assistance

It is essential to support accessibility features throughout eHealth app functionalities. Critical components for fulfilling eHealth app accessibility-related assistance and functionality issues include app operation instructions, assistive technologies, feedback loops, efficiency, correctness, compatibility, and appearance.

- **Clear and concise:** eHealth app's operational instructions should be clear and concise. For example, complex gesture controls that require multiple fingers or taps

for navigation can create significant challenges for end-users with dexterity impairments and users with no motor disabilities. The app should also include – proper guidance on enabling accessibility features, use clear and straightforward language, and provide explanations where necessary for people with cognitive disabilities, low literacy, and non-native speakers.

- **Predictable:** eHealth app elements should appear and operate in predictable ways. For instance, when the navigation option is hidden behind the menu icon, coded with links, or embedded within a list structure, the user should be able to identify them and perform corresponding actions, regardless of their experience or ability level.

- **Assistive technology:** Assistive technologies within an eHealth app should not automatically change the app's operational context unless advised by users. Avoiding duplicate attributes in-app control elements is recommended so that assistive technologies can recognize them without ambivalence. Furthermore, accessibility support and assistive technologies should follow standard conventions and perform equally well across various devices. For example, alternate keyboards that use head pointers, single switches, sip/puff, and other special input devices should follow the same standard working process across different devices.

- **Assistance:** eHealth app should include proper assistance during data input. For example, when input errors are detected, the app should suggest appropriate autocorrections. Critical user data requiring input for the app's correct functionality should be checked, i.e., context-sensitive help should always be available for endusers.

- **Reversible:** eHealth app should allow reversible actions. For example, user should be able to cancel an accidental trigger reversibly, such as through undo, abort or down/backspace click. This can be particularly helpful for users with limited motor skills or who struggle with precise movements and gesture control.

- **Motion:** Accessible and reduced motion preference can make eHealth app more effective for users with disabilities. For example, someone with a cerebral palsy group of the disorder may have involuntary movements and could accidentally trigger the motion control, or someone who is blind and uses a screen reader might want to turn off the motion control so that it does not interfere with their screen reader. This also helps reduce distractions or nausea from animated or moving content for those users.

- **Programmatic action:** All UI components, including those generated by scripts, should have their states, properties, and values that can be set and actions by the user as well as through the program. Notifications for changes to these items should also be available to the user's app. For example, an image with a text description should include an 'ALT' tag that describes the image's content, allowing screen readers to provide an audio description for the users who cannot see the image.

- **Testing:** eHealth apps should undergo accessibility testing to identify and fix relative issues. App developers should coordinate with users to perform regular accessibility testing, ensuring that the app meets user needs and is properly accessible to everyone.

- ❖ **Feedback:** eHealth apps should provide feedback to users when actions are performed through visual or auditory cues to help users to understand what is happening in the app. The app should also include feedback loops so that users can quickly and easily report any errors or issues, even their view on app efficiency and correctness, to the developers.

5 Reliability and Validity Guidelines

The reliability in eHealth apps refers to the app's ability to perform intended tasks accurately and consistently while remaining trustworthy. The eHealth app validity refers to the accuracy of the app outcomes, including data collection, measurement, recommendations, and results. We found that reliability and validity characteristics significantly build confidence among end-users and developers of eHealth apps. For users, it ensures that the app provides reliable and accurate information, while developers can ensure that the developed app serves its intended purpose.

In the following sections, we have presented reliability and validity guidelines for eHealth apps to make them more human centric, dividing them into two sections: Information, and Development and Maintenance.

5.1 Information

Ensuring appropriate reliability and validity of information is crucial for eHealth apps. We found that app developers can enhance the credibility of app information and establish trust among users when they are reliable and valid. Below we discuss our proposed guidelines for improving the reliability and validity of eHealth app information.

- ❖ **Decryption and disclosure:** The description of the eHealth app should be truthful, fair, and not misleading. Clear and accurate information in the app description largely builds trust among user communities. All claims about the app's capabilities should be self-evident and any relevant disclosures should be explicitly pointed out. For example, if additional fees are required to access some particular app functions, this information must be disclosed to prevent any deception.

- ❖ **Documentation and source:** To ensure the credibility of eHealth app information, it is essential to properly document all content with reference, e.g., clinical measurement outcomes, patient management functions, or data tracking results. The sources should be recognizable, authentic, and credible. They must align with current practice. However, when the source cannot be adequately identified, the app should include documentation of the content formulation and present relevant proof to establish trustworthiness. Then, all information in the app should also comply with all copyrights.

- ❖ **Advert:** eHealth app should enable users to distinguish between app information and advertising clearly. For example, advertisements should be placed in a manner that does not create confusion or uncertainty among users about advertising versus educational information. Additionally, all advertising should comply with applicable regulatory requirements and copyright policies. Developers need to disclose any advertising within the app, and they should not mislead users with false claims or overemphasize the benefits of advertised products or services.

5.2 App Development and Maintenance

In eHealth apps, continuous maintenance is needed to ensure the accuracy and consistency of outcomes in data collection, measurement, recommendations, results and so on. This helps to ensure that the app functions optimally and reliably, gaining users' trust. Examples of regular maintenance activities include updating security patches, upgrading app functionality, and fixing bugs to prevent data breaches and ensure that the app continues functioning as intended.

- ❖ **Update and changes:** eHealth app developers and development companies should maintain appropriate protocols to determine the need for app content updates. It is therefore, also crucial to inform the app users about key changes in the app. For example, changes in the app resulting from clinical or medical guidelines updates when an old version becomes obsolete. Then, any deviations in an app's content from the original source should be validated and explained to users to ensure transparency. For instance, if an app recommends a fitness plan that deviates from a current standard, the app should include an explanation of why the deviation is necessary and provide recognized sources to support its recommendation.

- ❖ **Interoperability:** eHealth apps should be able to appropriately integrate with other healthcare systems, e.g., electronic health records. It is recommended to use standardized protocols and formats for appropriate interoperability, such as using HL7 (Health Level Seven) for data exchange. For example, an eHealth app that monitors a previously hospitalized patient's vital signs could integrate with the patient's electronic health record to ensure that the patient's physician can access the most up-to-date information. This will improve the overall quality of care provided, ultimately creating a more effective eHealth app experiences.

- ❖ **Safety guidelines:** eHealth apps should contain safety guidelines with clear instructions on app usage, identifying potential risks and side effects. For example, an app that provides food recommendations should examine users' conditions before hand, especially if they have underlying health conditions such as food allergies. Similarly, a medication reminder app that reminds the user when to take their medication should also highlight the possible side effects that may occur when taking the medication. It helps users understand the risks and make informed decisions about differing conditions. The safety guidelines should contain developers or customer service contact in case the users experience problems while using the app.

- ❖ **User data:** eHealth app should only collect the minimal personal data necessary for the app's functionalities. For example, a medication tracking app only needs to collect the name of the medication, dosage, and frequency, not the user's name, address, or other personal information. Then, eHealth apps should give true impression to their users that they control their own data. For instance, when an app allows end-users to limit data sharing with third-party entities without user permission, the app gain more trust and end-users act as proprietors of the generated data. Overall, users should able to determine which data to be stored, deleted, or processed.

- ❖ **Policy statements:** eHealth apps should always maintain transparent 'terms of service' policy statements. The language used in these statements should be easy

to understand, free from technical jargon and legal language. It is recommended to display the policy statement during the app onboarding process. For example, a telemedicine app connecting patients with healthcare providers may display its 'terms of service' policy statement during onboarding. The statement could include information about how the app handles patient data, such as the data types collected, its use, and who has access to it. This largely helps in achieving trustworthiness and ensuring transparency.

- **Privacy:** eHealth apps should prioritize user privacy throughout the design and use of the apps. One recommended practice is to anonymize and encrypt any app-generated data stored for future actions. It ensures that individuals remain non-identifiable even if the data is accessed unauthorizedly or stolen. For example, a mental health app may collect data about a user's symptoms and use that data to provide personalized recommendations for therapy. By encrypting and anonymizing this data, the app developer can ensure that the user's personal information is protected, even if the app's servers are hacked.