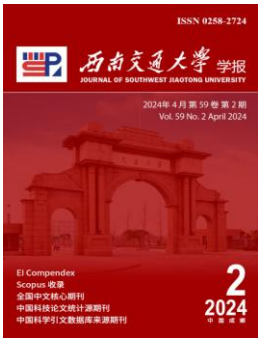


西南交通大学学报
JOURNAL OF SOUTHWEST JIAOTONG UNIVERSITY

第 59 卷 第 2 期
2024 年 4 月

Available online at http://jsju.org

Vol. 59 No. 2
April 2024

Open Access Article

https://doi.org/10.35741/issn.0258-2724.59.2.10

Research article

Computer and Information Science

MULTIPLE THEMES IN AUGMENTATIVE AND ALTERNATIVE COMMUNICATION MOBILE APPLICATION FOR AUTISTIC CHILDREN WITH SPEECH DIFFICULTIES

為有語言障礙的自閉症兒童提供多種主題的增強和另類交流移動應用程序

Lely Hiryanto [a,*], Hersinta [b], Olivia Deliani Hutagaol [b], Tony [a], Muhammad Tohir Rafly [a], Marchella Angelina [a], Jonathan [a], Henry Felix Hartanto [a], Lioviani Gavrilla [a]

[a] Faculty of Information Technology, Tarumanagara University
Jl. Letjen S. Parman No. 1 Grogol, Jakarta, Indonesia, lelyh@fti.untar.ac.id

[b] Faculty of Communication, London School of Public Relation
Jl. K.H. Mas Mansyur Kav. 35, Jakarta, Indonesia, hersinta@lspr.edu

* Corresponding author: lelyh@fti.untar.ac.id.

Received: January 10, 2024 ▪ Reviewed: February 4, 2024
▪ Accepted: March 1, 2024 ▪ Published: April 30, 2024

Abstract

This paper describes a new idea of implementing multiple themes to provide personalization for autistic users when using the Visually Interactive Communication and Reading Aid (VICARA) application. This study aims to improve the usability of VICARA 2.0 by introducing a concept of multiple themes that consider sensitivity to sounds and visuals and ease of use for its new version. VICARA is a mobile-based Augmentative and Alternative Communication (AAC) application that enables autistic children to communicate through visual images and picture-aided symbols with text and sound in Bahasa Indonesia. However, the previous version of VICARA has some limitations, namely, a lack of interactive communication features and user interface/user experience (UI/UX) suitable for autistic children with communication difficulties. This group of users needs special features and designs corresponding to their characteristics. Therefore, an application needs easy customizing adjustable to the unique qualities of its users. Design thinking methodology involved developing four UI/UX prototypes or themes carefully designed by following guidelines for developing and evaluating program applications targeting autistic users and using feedback from people interacting directly with autistic children. The evaluating prototypes involved qualitatively focus group discussions and quantitatively the System Usability Scale (SUS). The results show that each theme has an appealing and well-thought-out design and covers all the bases of the guidelines and standards used when creating an application for autistic

users. These positive results lead to good usability with an SUS score of 84.44, which falls into the excellent category. Therefore, the concept of multiple themes improves the usability of VICARA and applies to developing a more inclusive AAC application.

Keywords: augmentative and alternative communication, autism, speech, visually interactive communication and reading aid, user interface/user experience

摘要 本文描述了一種新的想法，即在使用視覺互動交流和閱讀輔助應用程式時實現多個主題，為自閉症用戶提供個人化服務。本研究旨在透過引入考慮對聲音和視覺的敏感性以及新版本的易用性的多個主題的概念來提高視覺互動交流與閱讀輔助 2.0 的可用性。視覺互動交流與閱讀輔助是一款基於行動裝置的增強和替代交流應用程序，使自閉症兒童能夠透過視覺圖像和圖片輔助符號以及印尼語的文字和聲音進行交流。然而，視覺互動交流與閱讀輔助先前的版本存在一些局限性，即缺乏適合溝通困難的自閉症兒童的互動溝通功能和使用者介面/使用者體驗。這群用戶需要符合他們特色的特殊功能和設計。因此，應用程式需要輕鬆定制，以適應其用戶的獨特品質。設計思維方法涉及開發四個使用者介面/使用者體驗原型或主題，這些原型或主題是按照開發和評估針對自閉症用戶的程式應用程式的指南以及使用與自閉症兒童直接互動的人的反饋精心設計的。評估原型涉及定性焦點小組討論和定量系統可用性量表。結果表明，每個主題都有一個吸引人且經過深思熟慮的設計，並涵蓋了為自閉症用戶創建應用程式時使用的指南和標準的所有基礎。這些積極的結果帶來了良好的可用性，系統可用性量表得分為 84.44，屬於優秀類別。因此，多主題的概念提高了視覺互動交流與閱讀輔助的可用性，適用於開發更具包容性的增強性和替代性溝通應用程式。

关键词: 增强和替代沟通、自闭症、言语、视觉互动沟通和阅读辅助、用户界面/用户体验

I. INTRODUCTION

Humans have different ways of communicating, although they mostly use speech (verbal) and nonspeech (nonverbal) ways to communicate [1], including individuals with autism spectrum disorder and communication difficulties. They face challenges in communicating verbally due to their differences in communication abilities. Autistic people exhibit a particular set of repetitive activities, severely constrained interests, and sensory behaviors that start very early in life [2], [3]. The prevalence of autistics in Indonesia is increasing by up to 15% every year [4]. The number of autistic children enrolled in conventional, specialized, and inclusive educational environments is uncertain [5]. However, many autistic children have no access to formal education in Indonesia [6]. Many autistic children experience communication issues that vary in severity; some children may be verbal, while others remain non-verbal or minimally verbal [7]. Previous studies have shown that at least 30% of children with autism have minimum verbal communication skills [8], [9]. Autistic children with speech disabilities have difficulties expressing their feelings, including their parents and teachers, frustrating both parties and leading to aggressive behavior [10], [11].

Augmentative and Alternative Communication (AAC) is a speech therapy that aims to assist people with speech difficulty in nonverbal ways [12] using pictures, body language, sign language, and generated speech devices. Previous studies [13] have shown that speech therapy that uses AAC is efficient in improving communication skills, social interaction, and academic performance, as well as in reducing the challenging behaviors of autistic children. Therefore, autistic children and other people with communication difficulties can benefit from AAC to accommodate their daily life communication [14].

People find interactions with digital technology enjoyable and engaging as they occur in a secure and trustworthy environment [15]. Developing various features and user-friendly visual displays on mobile devices has led to greater use among autistic people. For autistic people with difficulties in verbal communication, AAC applications on mobile devices, such as tablets and mobile phones, could be beneficial in enhancing and facilitating their daily

communication [8]. The applications can act as enabling tools for different ways of communication, as autistics can express their feelings and needs using pictures and sounds.

Visually Interactive Communication and Reading Aid (VICARA) has been designed and developed since 2013 as a Bahasa-Indonesia-based AAC application. VICARA is the result of interdisciplinary partnerships between the London School of Public Relations Jakarta and ICT Watch Indonesia, in collaboration with other institutions, including an academic institution (Universitas Multimedia Nusantara, Tangerang), digital creative business start-ups (Code Margonda and KREAVI), and the Center for ASEAN Autism Studies. They have developed two beta versions of VICARA. They are VICARA 1.0 and VICARA 2.0.

Hersinta et al. [16] conducted a Focus Group Discussion (FGD) with parents and teachers who have autistic children and speech difficulties as participants. The participants used VICARA 2.0 and evaluated them using a framework consisting of four factors: attractiveness, learnability, operability, and understandability, as used by Zapata et al. [17]. A questionnaire obtained feedback and evaluation after using the application. The results of the FGD and questionnaires discussed in [16] revealed that VICARA 2.0 was good enough in terms of the four abovementioned factors. The results from the FGD and the interview reported in [16] assume that VICARA 2.0 needs improvement for its layout and icons. Using its current UI, 50% of the participants required training and tutorials to use the application. It takes 30-60 min for them to use the application features. The author also reported that participants had difficulty navigating the application using features such as creating, archiving, and composing picture cards.

User Interface (UI) design deals with the visual elements of a digital product, while User eXperience (UX) design relates to the overall user's feelings, either satisfied or frustrated while using the product [18]. The UI design quality influences the results of UX [19]. Bad quality of UI design, e.g., the contrast between background and text is poor, and the font size is too small, causing a distressful feeling for the user. This negative experience needs exclusion when dealing with autistic users.

Autistic children more often have difficulties when accessing and using programs [10], [11], prone to sensory overload, and have a typical pattern of attention deficiency [20]. Furthermore, they often have limited cognitive function, whereby an individual with autism is only able to respond to a subset of the entire task or environmental stimuli [10]. Every individual with autism needs special features and designs corresponding to their characteristics. For example, a group of autistic children with a high level of sensitivity to color needs an application with a background and a choice of images with colors that are comfortable for them to see. Therefore, an application needs to be easily customized to adjust to the unique qualities of its users [21]. Using multiple design themes helps users to customize and personalize an application.

This paper aims to improve the usability of VICARA 2.0 by introducing a concept of multiple themes that consider sensitivity to sounds and visuals and ease of use for its new version. The target group is autistic children with speech difficulties. This paper extends three preliminary works [16], [22], and [23] by making the following contributions:

1. Conducting a literature study on guidelines for designing UI/UX for autistic people to find suitable and complete factors to consider when developing a mobile application for autistic users.
2. Employing design thinking methodology to develop four UI/UX design prototypes for VICARA multiple themes feature; to the best of our knowledge, our proposed new version of VICARA is the first AAC application that uses the concept of themes with different UI/UX design for personalization.
3. Evaluation of the usability of the four UI/UX prototypes using factors required in an application for autistic users and system usability scale (SUS).

II. LITERATURE REVIEW

The usability and accessibility of an application through its UI are essential [10], [24]. Autistic users more often have difficulties accessing and using the application's features. We study four guidelines for designing an application for autistic users. The Web Content Accessibility Guidelines (WCAG) 2.1 [25] provide guidelines for the accessibility of a website. The guide contains four principles that must be applied when designing and creating a user interface (UI). The four principles are as follows: (i) understanding information and UI elements through various kinds of physical sensory (perceivable), (ii) all UI and navigation elements must operate (operable), (iii) knowing the information and operation of the UI (understandable), and (iv) the content of the application can be translated by various kinds of user agents, including assistive technologies (robust). Examples of user agents are browsers,

media players, and other web content-rendering applications [25]. Assistive technologies include screen reader applications that read the contents of a computer screen, speech input applications that give commands to a computer to perform particular actions, and alternative input devices such as eye tracking and single switch entry [26]. This guide can also be used to program applications on mobile devices [27].

Alzahrani et al. [10] discussed the effect of HCI on autistic users. The usability and accessibility of the UI are critical parts of HCI because they affect the improvement of overall system performance, including user acceptance and satisfaction with an application program. The usability of the UI is essential, especially for people with autism, because they are likely to experience many problems when using the application. Designing UI/UX with accessibility aspects in mind allows people with physical disabilities to use, access features, interact, and contribute to application programs. WCAG guidelines consider every aspect of users with physical disabilities but few for users with cognitive disabilities [10].

The Academic Autism Spectrum Partnership in Research and Education (AASPIRE) proposed guidelines for creating accessible websites for autistic users [28], including physical, intellectual, and social accessibility for autistic adults.

Valencia et al. [21] conducted in-depth studies regarding the design and evaluation guidelines of UI/UX for an application used by autistic users. They compiled nine factors to guide the design. These factors are engaging, predictable, structured, interactive, generalizable, customizable, sense-aware, attention-retaining, and frustration-free. These nine factors, described in Table 1, provide more details in evaluating an application than FGDs and questionnaires. Further, the factors covered the guidelines recommended in [28].

Table 1.
Nine UI/UX factors [21]

Factor	Description
Engaging	Users are attracted to the application: ● A constant, concrete, and accurate feedback for user actions, ● Use rewards for user's good performance, ● Contain motivating elements such as games and attractive visual and audio features.
Predictable	Users can predict the results of the actions performed on the application by • Using generic icons for certain functions, e.g., login, settings, log out, back, delete, add, and edit, • Using other common elements to indicate a result if tapped, scrolled down, scrolled up, etc.
Structured	The application must be structured as follows: ● Graphics, navigation, and other interactive elements used in the application must be clearly organized, simple, and consistent throughout its usage.
Interactive	Interaction with the user: ● Adjustment to the characteristics, needs, and abilities of the user, and ● Activities that can be performed through the application should be designed simply and concisely, ● The purpose of the activity should be transparent, ● Memory load must be minimized, ● Short but clear use of language.
Generalizable	Users are familiar with the application: ● With the visual, audio, and input elements so that they can interpret the functions of these elements.
Customizable	Application personalization: ● Personalize aspects such as different application themes that use different colors, fonts, and layouts.
Sense aware	Considering the use sense: • Simple, easy to read, clear, and easy to understand layout, • Sufficient space between the elements, • Minimum aesthetic elements, • Do not use colors that can provoke anxiety and interfere with focus, such as colors that are too flashy (bright, bold, and intense), for example, bright red and orange, • Text in local and simple language; use more icons or symbols that are simple, standard, and clear, • Does not overwhelm the application with too much information, images, audio, and text, • If using voice to interact with users, the sound quality must be clear, simple, and unobtrusive, • Minimize physical movement by limiting it to touches on the screen and no touch interfaces such as the Optic Matrix Sensor with lenses that can detect eye movements that translating on-screen or mixed gestures.
Attention retaining	Maintaining user focus: • The transition time from action to result should be as minimal as possible, • Use of dynamic stimuli (personalization of image sliders, text on action-to-button, pop ups, banners) without interrupting focus or causing sensory overload.
Frustration free	Prevent users from becoming frustrated while using the application: • Error management to prevent, recognize, and recover,

Factor	Description
	• Provide clear and correct error messages using simple sentences that are easy for users to understand.

Assistive communication technology, such as tablet computers and mobile phones, and their applications support communication functions broadly [29]. In particular, it facilitates autistic children to have more control than when they interact directly with others [29] [30].

AAC implementation as a mobile application can be beneficial for people with communication difficulties, including non-speaking autistic users [16], [14]. Most current AAC mobile applications, namely Proloquo2Go [31], AAC Cboard [32], Leeloo [33], BerKata [34], and VICARA 2.0 [16], support only one theme for their user interface. Proloquo2Go [31] is widely used as a communication aid for autistic students and runs only on the iPad and iPhone. Another AAC application is Cboard [23], which is free and multilingual. Cboard is a web-based application that can run on various mobile devices, including tablet computers and mobile phones. The use of Cboard must be accompanied by an Internet connection to enable the use of Bahasa Indonesia for voice and text on the card. It cannot use features such as a camera and microphone. Leeloo [33] has features to support multiple languages, one of which is Bahasa Indonesia. However, Leeloo requires an external text-to-speech language generator. Another application that supports Bahasa Indonesia is BerKata [34].

A previous study on the use of VICARA 2.0 [16] revealed that while VICARA 2.0 was fairly good in terms of attractiveness, learnability, operability, and understandability factors, the respondents proposed to improve this current version in terms of its User Interface and User eXperience (UI/UX). This was because the participants would need 30 to 60 min to learn to use the application and they had difficulty in navigating some features like creating cards and composing picture cards.

Our preliminary work in [22] aimed to redesign VICARA. It proposed a new UI/UX design, which was then refined in [23]. It presented an attractive and well-thought-out UI/UX theme for VICARA, called Cheerful Tangerine, which follows the design and evaluation guidelines targeting autistic users [21]. This paper extends the two studies by adding three additional design themes following the same design and evaluation guidelines in [21] and one additional evaluation method using SUS [35].

III. METHODOLOGY

We used design thinking methodology [36] to develop four UI/UX prototypes as new themes for VICARA. Some studies, namely [29] and [30] used this methodology developing mobile applications for autistic users. As shown in Figure 1, the methodology consists of five stages: empathize, define, ideate, prototype, and test. The following five sections explain them in detail (Figure 1).

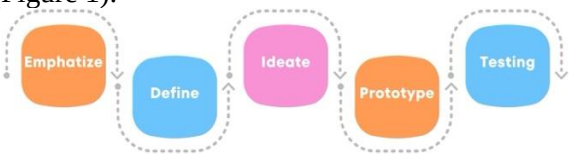


Figure 1. Design thinking methodology (The authors)

A. Empathize

This step studies the users' physical and emotional needs and how and why they do things. We conducted an FGD with parents, teachers, and a speech pathologist that interacts directly with autistic children with speech difficulties. From the FGD, we gained an understanding of the importance of AAC applications such as VICARA for these children to support their nonverbal communication while learning how to speak.

B. Define

This step defines the problem scope. We design four concepts of UI/UX themes for the new version of VICARA by following the guidelines in [21]. We developed four UI/UX prototypes, each for each theme, using Figma [37]. We use them to evaluate the concept of multiple themes to improve the usability of VICARA.

C. Ideate

In this step, we gather information from feedback obtained in the empathize step and from literature study to generate ideas for the new UI/UX design. The idea is to create four design concepts and use them to create multiple themes for the new version of VICARA. Each theme adopts the simple layouts and flows from AAC Cboard [32] and Leeloo [33] and the visualization of color composition and UI elements from Leeloo [33]. Furthermore, the new version has all VICARA 2.0 features and some additional features proposed by participants of the FGD conducted by [16].

D. Prototype

This step creates four UI/UX prototypes from

the four design concepts. Each prototype has the same features and functional flow but with a different UI design. The results and discussion sections provide more detail on the results of this step.

E. Testing

In this step, we conducted two FGDs. The first FGD involved three experts in autism and AAC technology. The experts used the nine factors defined in [21] to evaluate the four prototypes. The second FGD was conducted with nine teachers from a community-based education center called Rumah Belajar Cemara, which is located in Jakarta. In this research, we obtained feedback from them and considered them as our respondents to evaluate the usability of the four UI/UX prototypes. We used 10 questions of the SUS in [35] to obtain the SUS score and used its interpretation proposed in to obtain the overall usability category of the new version of VICARA.

IV. RESULTS

We named VICARA 2.0 with more features and four new design themes for its UI/UX as VICARA 3.0. Table 2 shows 10 features of VICARA 3.0. Three features are adopted from VICARA 2.0, while the other six are new features.

Table 2.
Features of VICARA 3.0 (The authors)

Features	Description
On-boarding	A welcoming screen that appears only after installation or the user logs out. It contains short information about VICARA and options for initial setup for the first installation or login to use the main features.
Card collections*	Display picture card collections.
Composing cards	Display all picture cards belonging to the same collection. A child user can learn to speak from any card that outputs audio or speech based on a word or a simple sentence in its label. All selected cards form a sentence ready to be sent as a message via WhatsApp.
Initial setup*	This feature runs after the application is installed. It asks for the name of the child user, one of the parents' email addresses as the account ID, password, pin number, and how well the child can speak.
Manage card collections*	Add, edit, and delete collection(s).
Manage cards	Add, edit, and delete picture card(s).
Manage account*	Change information related to the parents' email, password, and pin.
Language and storage setup*	Options for languages: default, Bahasa Indonesia or English; storage locations, local and/or cloud; and application themes.
Themes selection*	Record every activity of the child user while using the application.
Activity logs*	Record every activity of the child user while using the application.

* This feature does not exist in VICARA 2.0.

Table 3 specifies the visual elements of the UIs for the four themes: *SlateArv*, *Cheerful Tangerine*, *Creamy Pandan*, and *Shooting Star*. Each theme has its own color selection and different typography choices. The designed logo indicates that VICARA is a fun and playful application. Furthermore, the four characters motivate children to have fun while learning how to speak. They can choose a character that suits them. Figures 3-17 provide four UI samples for each feature listed in Table 2. In the last row of Table 3, we provide links (mockup) to access each theme's frame and navigation flow to show frame transitions and responses from any user action according to the flowchart in Figure 2. Each mockup provides users with the experience of using VICARA 3.0. Here, we use Figma [37] to create frames and wireframes to design the UI/UX for all features in Table 2.

Figure 2 shows the flowchart of VICARA 3.0. We add each UI to its related input and process our output diagram. The splash screen always appears every time the application is run. For a new installation, the user is navigated via the on-boarding page to the Initial Setup and then goes straight to picture card collections and next to picture cards for any selected collection. For existing users that are still logged in, it will go straight to Picture card collections. However, if a user is logged out, he or she needs to login back, also through the on-boarding page, so that it can then navigate to the card collections. Picture card collection and composition are two features that can be used by ASD children to communicate and learn to speak. From one of the two features, parents or teachers can enter parent mode by first tapping the icon lock three times and then entering the four-digit pin numbers. If users enter

the wrong pin three times, the parent mode will not be active. In contrast, if the PIN is correct, the user can manage (change, add, or delete) cards and collections, change the password and/or pin number, select a different theme for the application, and view the child activity log.

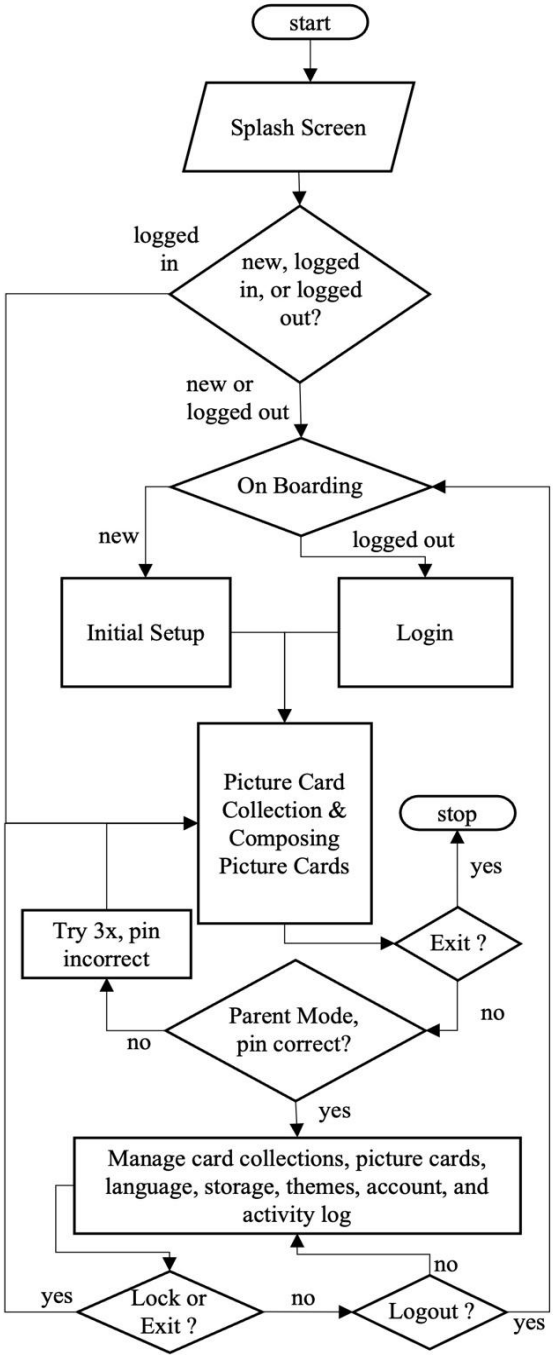


Figure 2. VICARA 3.0 flowchart (The authors)

Figure 3 shows the on-boarding feature for VICARA 2.0. As can be seen in the figure, VICARA 2.0 has three main features: creating picture cards; picture card collection; and composing audible picture cards to make a sentence and send it through WhatsApp. Note that VICARA 3.0 has the three main features of VICARA 2.0 and six additional features. They are initial setup, card collection, account management, language and storage setup, theme selection, and activity logs. Figure 4 shows the on-boarding UI of VICARA 3.0 for the four themes.

Figure 3. On-boarding in VICARA 2.0 (The authors)

Children and their parents or teachers can access the card collection. As can be seen in Figure 5, VICARA 2.0 does not categorize picture cards, whereas VICARA 3.0 (see Figures 6a to 6d) groups the cards into several categories to make them easier to find and better organized.

Figures 7 and 8, respectively, present the features of VICARA 2.0 and VICARA 3.0 for composing picture cards into a sentence. This feature is also accessible to both children and parents. Optionally, children can send the sentence to their parent's WhatsApp account. Note that each card's frame uses the Fitzgerald key code [38] as its background color based on the word classes represented in the card. For example, orange for nouns, yellow for pronouns, green for verbs, blue for adjectives, and brown for adverbs.

The next feature in both VICARA versions is the creation of picture cards. In VICARA 2.0, this feature is accessible to children. However, it is only accessible by parents and teachers in VICARA 3.0. The access limitation for this feature is important to prevent children from making unnecessary changes to the cards. This also prevents children from being involved in complex actions or making errors that may cause frustration.

As shown in Figure 9, VICARA 2.0 takes the image for the card either directly using the device's camera or from its local storage or gallery. Similarly, as can be seen from Figures 10a-10b, VICARA 3.0 obtains the image for the new card from either of the sources. However, VICARA 3.0 requires users to select the existing category for the new card before creating it. These two versions employ Google's text-to-speech API to produce spoken voice according to the text on each card.

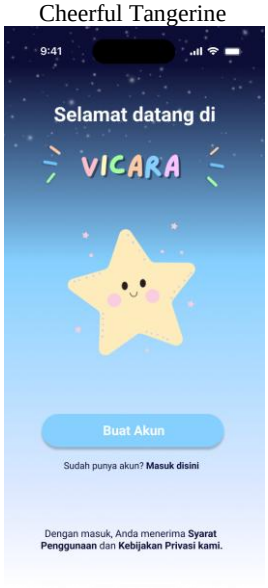
Table 3.
Specification of the visual elements of the four themes designed for VICARA 3.0 (The authors)

Elements	**UI/UX design themes (authors of the paper who developed the theme)**			
	SlateArv (Rafly)	**Cheerful Tangerine (Angelina & Jonathan)**	**Creamy Pandan (Hartanto)**	**Shooting Star (Gavrilla)**
Color	Calm, peaceful, and confident Success Information Warning Dangerous	Comfortable, warm, cheerful, and calm Sense of calm Soft and warm, positive vibe Balance and stability, sense of comfort	Soothing Resurrection Calm Positivity	Calm Relax Safe Comfortable Freedom
Typography	**Inter** Easy to read and can differentiate between ambiguous letters such as number 0 and letter o.	**DM Sans** Geometric, flexible, consistent, clean, and modern.	**Grandstander** Flexible, readable, and suitable for children	**Roboto** Readable, friendly, simple, consistent, and comfortable.
Logo				
Characters (Mascots)	 **Baby Greenmill** Baby version of a Greenmill who loves to joke and scare people.	 **Cheerful Chimi** Represents happiness to show the importance of smiling, laughing, and being happy	 **Happy Pandan** Expressing happiness	 **Happy** Happiness, uniqueness, and extraordinary
	 **Baby Reddish** Baby version of a Reddish that is friendly and supple.	 **Humble Fani** Represents modesty to show the importance of love and sincerity.	 **Surprised Pandan** Expressing a surprise feeling	 **Jolly** Great enthusiasm and eagerness
	 **Reddish** Character originates from a box of cherry candy, which is brave, strong, and sweet.	 **Sad Lulu** Represents feelings of sadness and worry, reminding us that it is normal to have such feelings.	 **Bored Pandan** Expressing boredom	 **Hoppy** Expectation and desire
	 **Greenmill** A character that originates from a swamp forest, which is gentle, slightly ridicule, and flabby.	 **Friendly Toni** Represents ethical value in socialization to remind us of the importance of developing social skills.	 **Peaceful Pandan** Expressing inner peace	 **Smarty** Knowledgeable and humble
UX (Figma presentation mode)	https://s.id/1WbTp (click the highlighted part of the UI)	https://s.id/1Wd0R (click the highlighted part of the UI and press space to fill the text field with a given text)	https://s.id/1WbU2 (click the highlighted part of the UI)	https://s.id/1X3o4 (click the highlighted part of the UI)

a. On-boarding in SlateArv

b. On-boarding in Cheerful Tangerine

c. On-boarding in Creamy Pandan



d. On-boarding a Shooting Star

Figure 4. User interface (UI) for on-boarding in VICARA 3.0 (The authors)

Figure 5. Card collection in VICARA 2.0 (The authors)

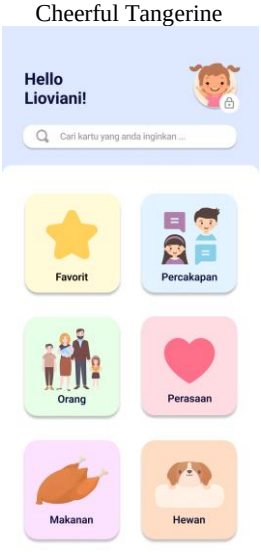
Figures 11-17 depict the six additional features existing only in VICARA 3.0 and accessible only by parents or teachers. For simplicity, we use each theme in turn to provide an UI sample of each additional feature.

Figure 11 shows the setup questions in the SlateArv theme. There are questions about the name of the child, the user's account, which is the parent's email and password, the parent's name and their WhatsApp number, the selection of avatar, and pin numbers. These questions are asked in the case of a new installation. Avatar selection is based on the mascots (characters) included for each theme. They can be used as a picture profile for the child.

a. Card collection in SlateArv

b. Card collection in a Cheerful Tangerine

c. Card collection in Creamy Pandan



d. Card collection in the Shooting Star

Figure 6. User interface (UI) for card collection in VICARA 3.0 (The authors)

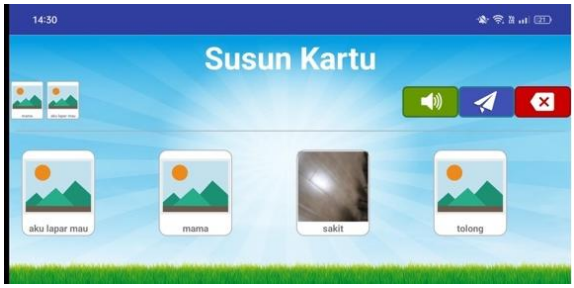
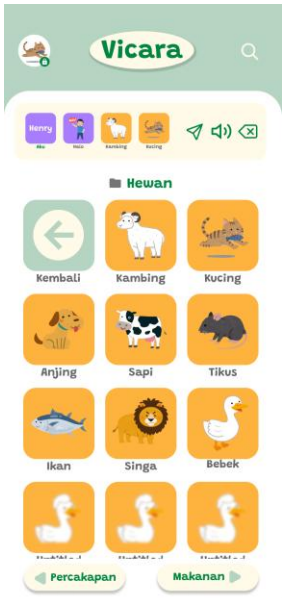


Figure 7. Composing cards in VICARA 2.0 (The authors)

a. Composing cards in SlateArv

b. Composing cards in Cheerful Tangerine



c. Composing cards in Creamy Pandan

d. Composing cards in the Shooting Star

Figure 8. User interface (UI) for composing audible picture cards to make sentences in VICARA 3.0 (The authors)

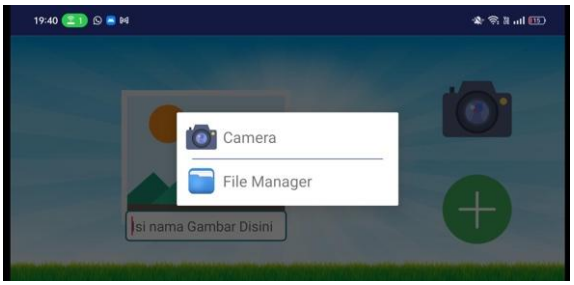
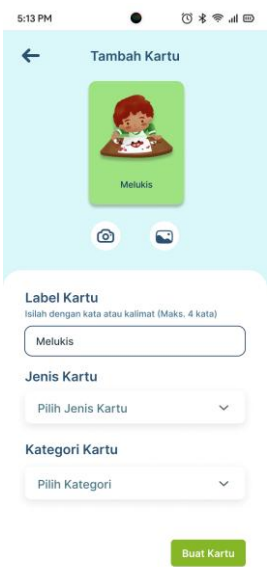
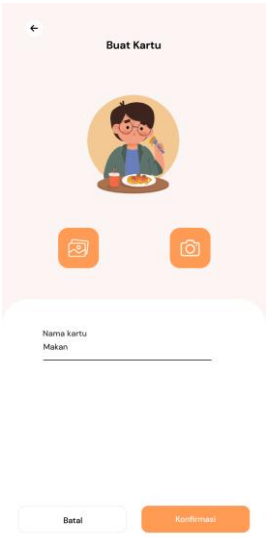


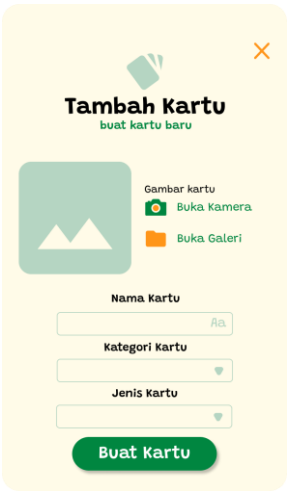
Figure 9. Create a card in VICARA 2.0 (The authors)



a. Create a card in SlateArv



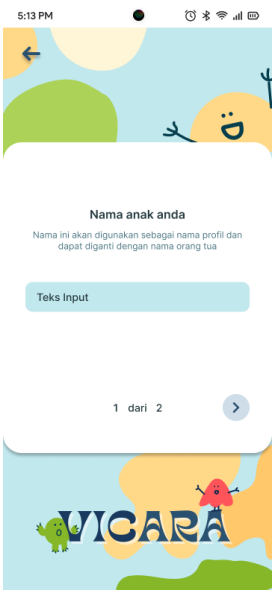
b. Create a card in Cheerful Tangerine



c. Create a card using Creamy Pandan

d. Create a card in Shooting Star

Figure 10. User interface for creating an audible picture card (The authors)



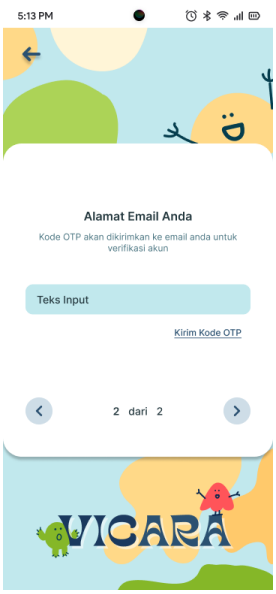


Figure 11. User interface for initial setup (The authors)

As shown in Figure 12, users can enter the parental mode by clicking the lock icon and typing pin numbers. In the parental mode, users can create a new category for cards and a new picture card, and perform some settings.

Figure 13 shows the list of settings that include managing language delivery (Bahasa Indonesia or English), storage location to save the picture cards (local or cloud), user account, theme selection, and activity log.

VICARA 3.0 provides a feature to personalize the application by changing its themes. Figure 14 shows the UI for listing the four themes from which users can choose.

Figure 15 shows the form to change the information inquiry that was filled out at the initial setup. It covers the user's details, such as the child's name, parent's email, password, pin number, and WhatsApp number.

Figure 12. User interface (UI) for entering parental mode in the Cheerful Tangerine theme (The authors)

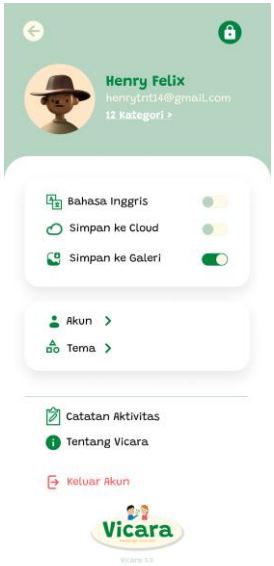


Figure 13. User interface (UI) for a list of settings in parental mode (The authors)

Moreover, VICARA 3.0 records every child activity when using card collection and composing card features to make a sentence in the activity logs shown in Figure 16. These logs will be used to monitor the progress of a child's speech acquisition.

In addition, VICARA 3.0 manages the collection category. As shown in Figure 17, users can add, edit, and delete categories. Note that the deletion of a category must be performed when it does not contain any picture cards.

Figure 14. User interface (UI) for theme selection (The authors)

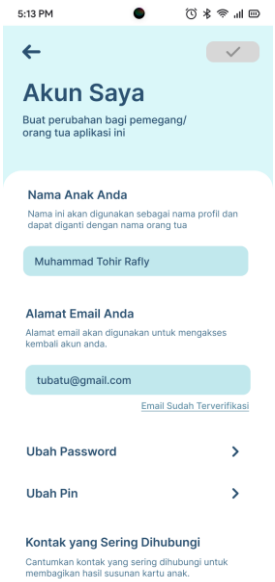


Figure 15. User interface (UI) for managing user accounts (The authors)

Figure 16. User interface (UI) for activity log (The authors)

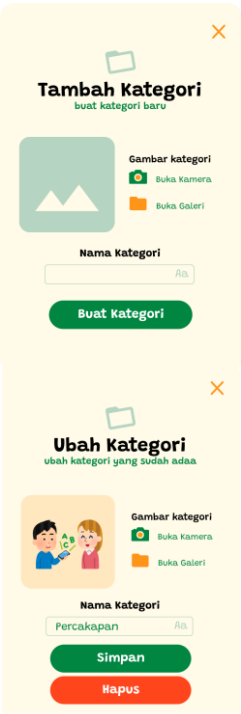


Figure 17. User interface (UI) for managing the collection categories (The authors)

V. Evaluation

This section discusses the evaluation of the four UI/UX prototypes, qualitatively using the guidelines [21] and quantitatively using the SUS score [35].

A. Qualitative Evaluation

We conducted the first FGD with three experts: an Internet Sehat promoter and enthusiast from ICT Watch Indonesia, a researcher from the Center of ASEAN Autism Studies based in LSPR Jakarta, and a Speech-Language Pathologist based in the Chrysallis Pediatric Development Facility located in Kembangan, Jakarta Barat. They evaluated the four prototypes with us.

The three experts provided positive feedback on our novel and well-considered design approach to create visually appealing multiple UI/UX themes for VICARA 3.0. We summarized their feedback on each UI/IUX prototype based on the nine UX factors identified in [21] to design and evaluate an application for ASD users as follows.

– *Engaging:* All experts agreed that visual elements in VICARA 3.0 are attractive and suitable for autistic children.

– *Predictable:* VICARA 3.0 is predictable because it uses familiar and common icons such as lock, arrow, magnifier, camera, adding symbol, and on/off slider. Furthermore, the use of the Fitzgerald key code as the background color of the picture card familiarizes children with the picture card objects in VICARA 3.0.

– *Structured:* All elements in each of the four prototypes, such as the layout, text, card shapes, and icons, are well organized, simple, and consistent. VICARA 3.0 compared with VICARA 2.0 categorized the picture cards so that users could easily find the required picture cards.

– *Interactive:* The UI of VICARA 3.0 has a clear, simple, and concise layout, and therefore, no overload of information. Providing multiple themes allows users to adjust the application according to their characteristics, needs, and abilities.

– *Generalizable:* VICARA 3.0 uses familiar and common elements for icons and navigation symbols. In this case, users know the functionality of each element and the response that they will receive after performing an action using it.

– *Customizable:* It is also customizable because it provides four design themes, which allow children to choose one that suits them. The experts observed that two themes, Cheerful Tangerine and Shooting Star, are most likely preferred by girls, while the other two themes, SlateARv and Creamy Pandan, are preferable for boys.

– *Sense aware:* VICARA 3.0 has a simple, clear, and easy layout, sufficient space between elements, use of pastel colors, text in local yet simple language, using more icons and images instead of long text, and requires only a touch screen without complicated physical movement, particularly for features used by children.

– *Attention retaining:* VICARA 3.0 allows children to select a theme they find more comfortable, with cute and motivating characters that they can interact with when using the application.

– *Frustration free:* Children have access only to view card collection and picture cards by simply tapping one or more picture cards that will generate spoken words (speech) according to the text on the cards. Therefore, each prototype ensured that when children use these accessible features, they engage in a convenient process and an almost error-free application.

In addition to the nine factors that are related to the interaction of austistic users with VICARA 3.0 itself, an expert from ICT Watch Indonesia pointed out the importance of data privacy. When using the application, VICARA 3.0 needs to securely store personal data such as parents' accounts (email, password, and pin number), their cellular phone numbers, and child's activity

logs when using the application.

Our expert in speech-language pathology assumed that VICARA 3.0 can be an example of an inclusive AAC application. The application can be used by users of all ages, genders, and physical and cognitive disorders, run on all devices, and includes all languages with their local accents. Furthermore, picture cards in VICARA 3.0 should follow standard picture exchange communication systems (PECS).

Our second FGD was performed with nine teachers from a community-based education center called Rumah Belajar Cemara located in Pulo Gadung Jakarta Timur, Indonesia. In this FGD, we presented VICARA 2.0 followed by VICARA 3.0 to show the improvement of the new version in terms of its UI/UX and features. The nine teachers confirmed this improvement. The teachers also shared some common suggestions.

Their first suggestion is related to the feature of composing picture cards to support children's social stories. These social stories use picture cards not only to create regular activities for children and introduce new activities to them. The second suggestion concerns the use of standardized picture cards, in addition to creating our own picture cards.

B. Quantitative Evaluation

We use the SUS in [36]. SUS has emerged as a crucial element in the field of UI/UX, providing insight into the usability and general quality of digital systems, such as mobile applications [24]. It consists of 10 standardized questions. Table 4 lists the questions and their scale values: 1 (strongly disagree), 2 (disagree), 3 (not sure), 4 (agree), and 5 (strongly agree). Odd-numbered questions are positive, while even-numbered questions are negative.

Table 4.
List of 10 SUS questions (The authors)

No.	Questions	Scale				
		SD	D	NS	A	SA
1	I think that I want to use the system frequently	1	2	3	4	5
2	I found the system unnecessarily complex	1	2	3	4	5
3	I thought the system was easy to use	1	2	3	4	5
4	I think that I would need the support of a technical person to use this system	1	2	3	4	5
5	I found that the various functions in this system were well integrated	1	2	3	4	5
6	I thought there was too much inconsistency in this system	1	2	3	4	5
7	I imagine that most people would learn to use this system very quickly	1	2	3	4	5
8	I found the system very cumbersome to use	1	2	3	4	5
9	I felt very confident using the system	1	2	3	4	5
10	I needed to learn many things before I could get started with this system	1	2	3	4	5

Notes: SD - strongly disagree, D - disagree, NS - not sure, A - agree, SA - strongly agree

In the second FGD discussed earlier, we asked nine teachers to be our respondents for measuring the usability of VICARA 3.0 with its four prototypes. We asked them to select one of the five scale values that they felt suitable after experiencing each prototype with the four themes: *SlateArv*, *Cheerful Tangerine*, *Creamy Pandan*, and *Shooting Star*.

We obtained feedback from these nine teachers and considered them able to evaluate the usability of VICARA 3.0 with its four UI/UX prototypes using the above scale values.

Table 5 provides the overall feedback for the four prototypes in the form of scale values for each question. The point for each odd-numbered question is the selected scale value minus 1, whereas the point for every even-numbered question is five minus the selected score value. The total score for each question shown in Table 4 is the multiplication of the total points by 2.5. The SUS score is the average of the total scores over the number of respondents.

Table 5.
Calculation of the SUS score (The authors)

R	Points per question										Total	Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
1	2	4	1	3	2	3	2	2	1	4	24	60
2	4	4	4	4	4	4	4	4	4	4	40	100
3	4	3	3	4	4	3	3	3	4	3	34	85
4	3	3	4	3	3	3	2	3	3	3	30	75
5	4	3	2	4	2	2	2	2	2	4	27	67.5
6	4	4	4	4	4	4	4	4	3	4	39	97.5

Continuation of Table 5												
7	4	4	4	4	4	3	4	4	4	2	37	92.5
8	2	4	4	4	2	4	3	4	4	4	35	87.5
9	4	4	2	4	4	4	4	4	4	4	38	95
SUS Score												84.44

Notes:

- R = respondents (the nine teachers from Rumah Belajar Cemara)
- For Q1, Q3, Q5, Q7, Q9, point = Scale 1
- For Q2, Q4, Q6, Q8, and Q10, point = 5-scale
- Total = sum of all points
- Score = total 2.5
- SUS score = total score divided by the number of respondents

Figure 18 provides three types of interpretation of the SUS score: adjective ratings, acceptability scores, and school grading scales. The overall score of the four UI/UX prototypes of VICARA 3.0 is 84.44. Based on the interpretation of the SUS score in Figure 17, VICARA 3.0 with its multiple themes (i.e., the four UI/UX prototypes) falls into the excellent rating or Grade B. This result indicates that the implementation of multiple themes for VICARA is acceptable.

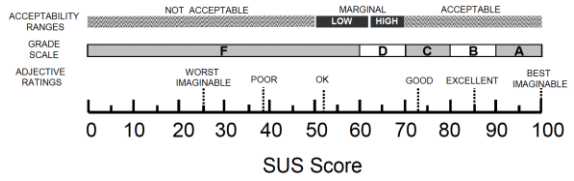


Figure 18. A comparison of adjective ratings, acceptability scores, and school grading scales in relation to the SUS score [35]

VI. DISCUSSION

The evaluation results using the nine UX design and evaluation factors in [21] and the SUS score provide some findings for this research. These findings identify the novelty and limitations of the current proposed features of VICARA 3.0.

First, the four UI/UX themes of VICARA 3.0 have met all aspects considered in the guidelines. However, the feedback concerning the data privacy and inclusiveness of VICARA from our two experts highlighted the limitations of the current proposed features of VICARA 3.0. They are data privacy, aspects of inclusiveness of VICARA 3.0, increasing the current composing cards feature to be able to create social stories, and the use of standard picture cards PECS.

Some aspects of inclusiveness have been covered in VICARA 3.0. In terms of usability by users for any gender, two themes, i.e., Cheerful Tangerine and Shooting Star, are more likely to be used by girls, whereas the other two themes are for boys. However, the four designs were targeted at autistic children. Therefore, the current themes in VICARA 3.0 are still limited in terms of age groups. Another limitation is that VICARA 3.0 is targeted at users in Indonesia, and the supported languages are only Bahasa Indonesia and English. Moreover, support for other physical disabilities is limited to the accessibility provided by the device that runs VICARA 3.0. Finally, other than autism, other cognitive disorders are beyond the scope of VICARA 3.0's features. Note that limited support for physical and cognitive disorders is also present in other AAC applications, such as Proloquo2go, Cboard, Leelo, and BerKata.

Second, VICARA 2.0's theme was graded as fairly good in a previous evaluation [16]. Furthermore, our experts and respondents confirmed that the four themes of VICARA 3.0 are more attractive than the single theme used by VICARA 2.0. With the SUS score categorized as excellent, VICARA 3.0 with its multiple themes and additional features has successfully improved the usability of VICARA 2.0.

Finally, our work considers a mixed method that uses both qualitative and quantitative methods. The previous studies in [22] and [23] evaluated the usability of the single-theme VICARA 3.0 only qualitatively through interviews with experts. Hersinta et al. [16] also used a mixed method. However, their qualitative evaluation of the single-theme VICARA 2.0 was based only on attractiveness, learnability, operability, and understandability factors. On the other hand, our study considers nine factors that cover more detailed aspects of the four factors and other factors applicable to autistic users, such as sense awareness, attention retention, and frustration-free.

VII. CONCLUSION

We have proposed a new idea of using multiple UI/UX themes to improve the usability of VICARA to provide access for autistic children who have difficulties verbally communicating and interacting. Unlike the other studies, we follow nine UX design factors for users with physical and cognitive disabilities,

including those with autism, designing four UI/UX prototypes. The qualitative evaluation of prototypes uses the same nine factors through two FGDs and quantitatively using a survey based on a standard usability score. The results show that the four UI/UX prototypes of VICARA 3.0 have met all guideline requirements. Moreover, their usability, measured by the SUS score, is in the excellent category. The results imply that the multiple themes can accommodate different needs and characteristics of autistic users.

Aside from the positive results, the qualitative evaluation identifies some limitations concerning the scope of all themes' features. They are related to data privacy, theme UI design for other age groups, support for languages other than Bahasa Indonesia and English, and accessibility for all physical and cognitive disorders. We designed VICARA 3.0 for non-speaking autistic children with all text elements and speech generated from each picture card by default in Bahasa Indonesia and optionally in English. However, a fully inclusive AAC application should include these limitations as its features. In addition, to attract users who use the app regularly, you can incorporate additional themes tailored to them. For future work, we will address them in stages, with the first stage focusing on developing the four UI/UX prototypes into a mobile application that includes a set of standard picture cards following the Picture Exchange Card System (PECS), ensuring data privacy, and incorporating social stories feature.

ACKNOWLEDGMENT

This work resulted from research supported by the Directorate General of Higher Education, Ministry of Education, Culture, Research, and Technology, Indonesia for the funding year 2023.

DECLARATIONS

Author Contributions

Conceptualization, L.H. and H.; methodology, L.H.; software, M.T.R., M.A., J., H.F.H. and L.G.; validation, O.D.H.; formal analysis, O.D.H.; investigation, L.H.; resources, T.; data curation, O.D.H.; writing—original draft preparation, H.; writing—review and editing, T.; visualization, M.T.R., M.A., J., H.F.H. and L.G.; supervision, L.H.; project administration, T.; funding acquisition, T. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data presented in this study are available upon request from the corresponding author. The data are not publicly available because the authors did not collect consent from respondents to disclose their answers for the usability survey. Furthermore, access to assets for the four UI/UX design themes is limited to view only due to copyright issues from the creators of each theme, who allow only VICARA to use their design.

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

[1] ALANT, E., BORNMAN, J., and LLOYD, L.L. (2006) Issues in AAC research: How much do we really understand? *Disability and Rehabilitation*, 28 (3), pp. 143-150. DOI: 10.1080/09638280500077986.

[2] LORD, C., ELSABBAGH, M., BAIRD, G., and VEENSTRA-VANDERWEELE, J. (2018) Autism spectrum disorder. *The Lancet*, 392, 10146, pp. 508-520. DOI: 10.1016/S0140-6736(18)31129-2.

[3] LORD, C., BRUGHA, T.S., CHARMAN, T., CUSACK, J., DUMAS, G., FRAZIER, T., JONES, E.J.H., JONES, R.M., PICKLES, A., STATE, M.W., TAYLOR, JULIE L., and VEENSTRA-VANDERWEELE, J. (2020) Autism spectrum disorder. *Nature Reviews Disease Primers*, 6 (1), article number: 5. DOI: 10.1038/s41572-019-0138-4.

[4] RIANY, Y.E., CUSKELLY, M., and MEREDITH, P. (2016) Cultural Beliefs about Autism in Indonesia. *International Journal of Disability, Development and Education*, 63 (6), pp. 623-640. DOI: 10.1080/1034912X.2016.1142069.

[5] BELLA, A., and DARTANTO, T. (2018) Persons with Disabilities (PWD) and Poverty in Indonesia. *Malaysian Journal of Economic Studies*, 55 (2), pp. 167-188. DOI: 10.22452/MJES.vol55no2.2.

[6] SHEEHY, K., KAYE, H., and ROFIAH, K. (2019) Indonesian Educators' Knowledge and Beliefs about Teaching Children with

Autism. *Athens Journal of Education*, 7 (1), pp. 77-98. DOI: 10.30958/aje.7-1-4.
[7] VOGINDROUKAS, I., STANKOVA, M., CHELAS, E.-N., and PROEDROU, A. (2022) Language and Speech Characteristics in Autism. *Neuropsychiatric Disease and Treatment*, 18, pp. 2367-2377. DOI: 10.2147/NDT.S331987.
[8] LORAH, E.R., HOLYFIELD, C., MILLER, J., GRIFFEN, B., and LINDBLOOM, C. (2022) A Systematic Review of Research Comparing Mobile Technology Speech-Generating Devices to Other AAC Modes with Individuals with Autism Spectrum Disorder. *Journal of Developmental and Physical Disabilities*, 34 (2), pp. 187-210. DOI: 10.1007/s10882-021-09803-y.
[9] NORRELGEN, F., FERNELL, E., ERIKSSON, M., HEDVALL, Å., PERSSON, C., SJÖLIN, M., GILLBERG, C., and KJELLMER, L. (2015) Children with autism spectrum disorders who do not develop phrase speech in the preschool years. *Autism*, 19 (8), pp. 934-943. DOI: 10.1177/1362361314556782.
[10] ALZAHRANI, M., UITDENBOGERD, A.L., and SPICHKOVA, M. (2021) Human-Computer Interaction: Influences on Autistic Users. *Procedia Computer Science*, 192, pp. 4691-4700. DOI: 10.1016/j.procs.2021.09.247.
[11] CARIA, S., PATERNÒ, F., SANTORO, C., and SEMUCCI, V. (2018) The Design of Web Games for Helping Young High-Functioning Autistics in Learning How to Manage Money. *Mobile Networks and Applications*, 23 (6), pp. 1735-1748. DOI: 10.1007/s11036-018-1069-0.
[12] ELSAHAR, Y., HU, S., BOUAZZA-MAROUF, K., KERR, D., and MANSOR, A. (2019) Augmentative and Alternative Communication (AAC) Advances: A Review of Configurations for Individuals with a Speech Disability. *Sensors*, 19 (8), 1911. DOI: 10.3390/s19081911.
[13] HOLYFIELD, C., DRAGER, K.D.R., KREMKOW, J.M.D., and LIGHT, J. (2017) Systematic review of AAC intervention research for adolescents and adults with autism spectrum disorder. *Augmentative and Alternative Communication*, 33 (4), pp. 201-212. DOI: 10.1080/07434618.2017.1370495.
[14] BAGAWAN, A., DOUGLAS, S.N., and DUNKEL-JACKSON, S. (2024) Indonesian Caregivers' Perspectives on the Use of Augmentative and Alternative Communication for Children with Autism Spectrum Disorder. *Journal of International Special Needs Education*, 27 (1), pp. 12-22. DOI: 10.9782/JISNE-D-23-00007.
[15] VALENCIA, K., RUSU, C., QUIÑONES, D., and JAMET, E. (2019) The Impact of Technology on People with Autism Spectrum Disorder: A Systematic Literature Review. *Sensors*, 19 (20), 4485. DOI: 10.3390/s19204485.
[16] HERSINTA, H., BANGUN, C.R.A., and HUTAGAOL, O.D. (2023) Developing VICARA 2.0: Exploring the potential use of augmentative and alternative communication (AAC) apps for the parents and teachers of autistic students. In: *Proceedings of the Sixth International Conference of Mathematical Sciences (ICMS 2022)*, 020120. DOI: 10.1063/5.0127048.
[17] ZAPATA, B.C., FERNÁNDEZ-ALEMÁN, J.L., IDRI A., and TOVAL, A. (2015) Empirical Studies on Usability of mHealth Apps: A Systematic Literature Review. *Journal of Medical Systems*, 39 (2), article number 1. DOI: 10.1007/s10916-014-0182-2.
[18] FILIPIUK, M. (2021) *UI Design Principles*. Available from: https://www.goodreads.com/book/show/57633909-ui-design-principles
[19] REZAE, M., CHEN, N., MCMEEKIN, D., TAN, T., KRISHNA, A., and LEE, H. (2020) The evaluation of a mobile user interface for people on the autism spectrum: An eye movement study. *International Journal of Human-Computer Studies*, 142, 102462. DOI: 10.1016/j.ijhcs.2020.102462.
[20] CRANE, L., GODDARD, L., and PRING, L. (2009) Sensory processing in adults with autism spectrum disorders. *Autism*, 13 (3), pp. 215-228. DOI: 10.1177/1362361309103794.
[21] VALENCIA, K., RUSU, C., and BOTELLA, F. (2021) User Experience Factors for People with Autism Spectrum Disorder. *Applied Sciences*, 11 (21), 10469. DOI: 10.3390/app112110469.

[22] TONY, HIRYANTO, L., and LIE, N.N. (2023) Mobile Application User Interface Design as a Visual Communication Tool for Autistic Children for ICT Watch. *Serina Abdimas Journal*, 1 (2), pp. 622-631. DOI: 10.24912/jsa.v1i2.25800.
[23] HIRYANTO L., ANGELINA M., JONATHAN, HERSINTA, HUTAGAOL, O.D. and TONY (2023) UI/UX Prototype of Visually Interactive Communication and Reading Aid for Autistic Children with Speech Disability. In: *2023 Eighth International Conference on Informatics and Computing (ICIC)*, Malang. pp. 1-6.
[24] PRASEPTIAWAN, M., UNTORO, M.C., FAHRIANTO, F., PRABANDARI, P.R., and WISNUBROTO, M.S. (2023) Redesigning UI/UX of a Mobile Application Using Task Centered System Design Approach. *Applied Information System and Management*, 6 (1), pp. 21-28. DOI: 10.15408/aism.v6i1.24665.
[25] W3C (2023) *Web Content Accessibility Guidelines (WCAG) 2.1.023*. Available from: https://www.w3.org/TR/WCAG21/
[26] UC BERKELEY (2023) *Berkeley Digital Accessibility. Types of Assistive Technology*. Available from: https://dap.berkeley.edu/types-assistive-technology
[27] W3C (2015) *Mobile accessibility: how WCAG 2.0 and other W3C/WAI guidelines apply to mobile*. Available from: https://www.w3.org/TR/mobile-accessibility-mapping/
[28] RAYMAKER, D.M., KAPP, S.K., MCDONALD, K.E., WEINER, M., ASHKENAZY, E., and NICOLAIDIS, C. (2019) Development of the AASPIRE Web Accessibility Guidelines for Autistic Web Users. *Autism in Adulthood*, 1 (2), pp. 146-157. DOI: 10.1089/aut.2018.0020.
[29] O'ROURKE, J., KUEH, C., HOLLY, C., BROOK, L., and ERICKSON, C. (2023) Co-designing a communication app to enhance collaborative communication support for secondary students with autism. *Educational Technology Research and Development*, 71 (2), pp. 579-604. DOI: 10.1007/s11423-022-10170-4.
[30] AMADO, M.L., and ARENAS, L.A. (2023) Mobile Prototype for the Early Stimulation of Autistic Children with Augmented Reality. *International Journal of Emerging Technology and Advanced Engineering*, 13 (3), pp. 1-12. DOI: 10.46338/ijetae0323_01.
[31] ASSISTIVEWARE (2024) Proloquo2Go: *The world's most popular AAC app for iPad and iPhone*. Available from: https://www.assistiveware.com/products/proloquo2go
[32] CBOARD (2024) *Communication for Everyone*. [Online]. Available from: https://www.cboard.io/#:~:text=Communication%20for%20everyone,and%20text%2Dto%2Dspeech
[33] GOOGLE PLAY APPS (2023) *Dream Oriented Leeloo AAC – Autism Speech App*. Available from: https://play.google.com/store/apps/details?id=org.dreamoriented.leeloo&hl=en-ID&pli=1
[34] BERKATA (2024) *Getting to know AAC BerKata*. Available from: https://aacberkata.com/#:~:text=Mengenal%20AAC%20BerKata,mudah%20membagikan%20kebutuhannya%20dalam%20kata
[35] BANGOR, A., KORTUM, P.T., and MILLER, J. (2009) Determining what individual SUS scores mean: adding an adjective rating scale. *Journal of Usability Studies*, 4 (3), pp. 114-123.
[36] INGLE B.R. (2013) Introduction to Design Thinking. In: *Design Thinking for Entrepreneurs and Small Businesses*, Berkeley, CA: Apress, pp. 1-15. DOI: 10.1007/978-1-4302-6182-7_1.
[37] FIGMA (2024) *How you design, align, and build matters. Do it together with Figma*. Available from: https://www.figma.com/
[38] COMMUNICATION COMMUNITY (2024) Fitzgerald Key for AAC. Available from: https://www.communicationcommunity.com/fitzgerald-key-for-aac/

参考文:

[1] ALANT, E.、BORNMAN, J. 和 LLOYD, L.L. (2006) 亚克力研究中的問題：我們真正了解多少？殘障與康復，28 (3)，第 143-150 頁。DOI：

10.1080/09638280500077986。
[2] LORD, C. 、 ELSBABAGH, M. 、 BAIRD, G. 和 VEENSTRA-VANDERWEELE, J. (2018) 自閉症譜系障礙。《柳葉刀》，392, 10146，第 508-520 頁。DOI：10.1016/S0140-6736(18)31129-2。
[3] 羅德，C.，布魯格，T.S.，查曼，T.，庫薩克，J.，杜馬斯，G.，弗雷澤，T.，瓊斯，E.J.H.，瓊斯，R.M.，皮克爾斯，A.，州，M.W.，泰勒、JULIE L. 和 VEENSTRA-VANDERWEELE, J. (2020) 自閉症譜系障礙。《自然評論疾病入門》，6 (1)，文章編號：5。
[4] RIANY, Y.E. 、 CUSKELLY, M. 和 MREDITH, P. (2016) 關於印尼自閉症的文化信念。國際殘疾、發展和教育雜誌，63 (6)，第 623-640 頁。DOI：10.1080/1034912X.2016.1142069。
[5] BELLA, A. 和 DARTANTO, T. (2018) 印尼殘疾人與貧窮。馬來西亞經濟研究雜誌，55 (2)，第 167-188 頁。DOI：10.22452/MJES.vol55no2.2。
[6] SHEEHY, K.、KAYE, H. 和 ROFIAH, K. (2019) 印尼教育工作者對自閉症兒童教學的知識和信念。雅典教育雜誌，7 (1)，第 77-98 頁。DOI：10.30958/aje.7-1-4。
[7] VOGINDROUKAS, I.、STANKOVA, M.、CHELAS, E.-N. 和 PROEDROU, A. (2022) 自閉症的語言和言語特徵。神經精神疾病與治療，18，第 2367-2377 頁。DOI：10.2147/NDT.S331987。
[8] LORAH, E.R. 、 HOLYFIELD, C. 、 MILLER, J. 、 GRIFFEN, B. 和 LINDBLOOM, C. (2022) 對自閉症患者行動技術語音生成設備與其他亞克力模式進行比較的研究的系統回顧頻譜紊亂。發育和身體殘疾雜誌，34 (2)，第 187-210 頁。DOI：10.1007/s10882-021-09803-y。
[9] NORRELGEN, F.、FERNELL, E.、ERIKSSON, M. 、 HEDVALL, Å. 、 PERSSON, C.、SJÖLIN, M.、GILLBERG, C. 和 KJELLMER, L. (2015) 自閉症譜系兒童在學齡前階段不發展短語言語的障礙。自閉症，19 (8)，第 934-943 頁。DOI：10.1177/1362361314556782。
[10] ALZAHRANI, M. 、 UITDENBOGERD, A.L. 和 SPICHKOVA, M. (2021) 人機互動：對自閉症使用者的影響。普羅奇迪亞計算機科學，192，第 4691-4700 頁。DOI：10.1016/j.procs.2021.09.247。
[11] CARIA, S. 、 PATERNÒ, F. 、 SANTORO, C. 和 SEMUCCI, V. (2018) 幫助年輕高功能自閉症患者學習如何理財的網頁遊戲設計。行動網路與應用，23 (6)，第 1735-1748 頁。DOI：10.1007/s11036-018-1069-0。
[12] ELSAHAR, Y.、HU, S.、BOUAZZA-MAROUF, K.、KERR, D. 和 MANSOR, A. (2019) 增強和替代性溝通進展：對具有言語障礙。感測器，19 (8)，1911。
[13] HOLYFIELD, C.、DRAGER, K.D.R. 、KREMKOW, J.M.D. 和 LIGHT, J. (2017) 對患有自閉症譜系障礙的青少年和成人的亞克力幹預研究進行系統評價。增強性和替代性溝通，33 (4)，第 201-212 頁。DOI：10.1080/07434618.2017.1370495。
[14] BAGAWAN, A.、DOUGLAS, S.N. 和 DUNKEL-JACKSON, S. (2024) 印尼照顧者對自閉症譜系障礙兒童使用增強性和替代性溝通的看法。國際特殊需求教育雜誌，27 (1)，第 12-22 頁。DOI：10.9782/JISNE-D-23-00007。
[15] VALENCIA, K. 、 RUSU, C. 、 QUIÑONES, D. 和 JAMET, E. (2019) 技術對自閉症譜系障礙患者的影響：系統性文獻回顧。感測器，19 (20), 4485。
[16] HERSINTA, H.、BANGUN, C.R.A. 和 HUTAGAOL, O.D. (2023) 開發维卡拉 2.0：探索增強和替代溝通應用程式對自閉症學生的家長和老師的潛在用途。請參閱：第六屆國際數學科學會議論文集 (ICMS 2022)，020120。
[17] ZAPATA, B.C. 、 FERNÁNDEZ-ALEMÁN, J.L.、IDRI A. 和 TOVAL, A. (2015) 行動醫療應用程式可用性的實證研究：系統性文獻回顧。《醫療系統雜誌》，39 (2)，文章編號 1。
[18] FILIPIUK, M. (2021) 用户界面設計原則。可從：https://www.goodreads.com/book/show/5763

3909-ui-design-principles
[19] REZAE, M. 、 CHEN, N. 、 MCMEEKIN, D.、TAN, T.、KRISHNA, A. 和 LEE, H. (2020) 針對自閉症譜係人士的行動使用者介面評估：眼動研究。國際人機研究雜誌，142, 102462。
[20] CRANE, L. 、 GODDARD, L. 和 PRING, L. (2009) 患有自閉症譜系障礙的成年人的感覺處理。自閉症，13 (3)，第 215-228 頁 。 DOI ： 10.1177/1362361309103794。
[21] VALENCIA, K. 、 RUSU, C. 和 BOTELLA, F. (2021) 自閉症譜系障礙患者的使用者體驗因素。應用科學，11 (21), 10469。
[22] 東尼，HIRYANTO，L. 和 LIE，N.N. (2023) 行動應用程式使用者介面設計作為資訊通訊技術觀察自閉症兒童的視覺溝通工具。塞琳娜· 阿卜迪馬斯期刊，1 (2)，第 622-631 頁 。 DOI ： 10.24912/jsa.v1i2.25800。
[23] HIRYANTO L.、ANGELINA M.、JONATHAN、HERSINTA、HUTAGAOL、O.D. 以及 TONY (2023) 針對有言語障礙的自閉症兒童的視覺互動交流和閱讀輔助的用户界面/用户体验原型。於：2023 年第八屆國際資訊與計算會議(ICIC)，瑪瑯。 第 1-6 頁。
[24] PRASEPTIAWAN, M. 、 UNTORO, M.C.、FAHRIANTO, F.、PRABANDARI, P.R. 與 WISNUBROTO, M.S. (2023) 使用以任務為中心的系統設計方法重新設計行動應用程式的用户界面/用户体验。應用資訊系統與管理，6 (1)，第 21-28 頁。DOI：10.15408/aism.v6i1.24665。
[25] 万维网联盟 (2023) 網頁內容可存取性指南(世界煤气协会) 2.1.023。可從：https://www.w3.org/TR/WCAG21/
[26] 加州大學柏克萊分校 (2023) 柏克萊數位無障礙。輔助技術的類型。可從：https://dap.berkeley.edu/types-assistive-technology
[27] 万维网联盟 (2015) 行動可近性：世界煤气协会 2.0 和其他万维网联盟/瓦伊指南如何應用於行動。可從：https://www.w3.org/TR/mobile-accessibility-mapping/
[28] RAYMAKER, D.M.、KAPP, S.K.、MCDONALD, K.E. 、 WEINER, M. 、 ASHKENAZY, E. 和 NICOLAIDIS, C. (2019) 針對自閉症网络使用者的阿斯皮尔网站可存取性指南的製定。成年自閉症，1 (2) ， 第 146-157 頁 。 DOI ： 10.1089/aut.2018.0020。
[29] O'ROURKE, J.、KUEH, C.、HOLLY, C.、BROOK, L. 和 ERICKSON, C. (2023) 共同設計一款交流應用程序，以增強對自閉症中學生的協作交流支持。教育科技研究與發展，71 (2)，第 579-604 頁。DOI：10.1007/s11423-022-10170-4。
[30] AMADO, M.L. 和 ARENAS, L.A. (2023) 透過擴增實境對自閉症兒童進行早期刺激的移動原型。國際新興技術和先進工程雜誌，13 (3)，第 1-12 頁。DOI：10.46338/ijetae0323_01。
[31] 辅助软件 (2024) Proloquo2Go：世界上最受歡迎的 iPad 和 iPhone 亚克力應用程式。可從：https://www.assistiveware.com/products/proloquo2go
[32] 董事会 (2024) 每個人的溝通。[線上的] 。可從：https://www.cboard.io/#:~:text=Communication%20for%20everyone,and%20text%2Dto%2Dspeech
[33] 谷歌游戏应用程序 (2023) 夢想導向里洛亚克力-自閉症語音應用程式。可見：https://play.google.com/store/apps/details?id=org.dreamoriented.leeloo&hl=en-ID&pli=1
[34] 贝尔卡塔 (2024) 了解亚克力 伯卡塔。資料來源：https://aacberkata.com/#:~:text=Mengenal%20AAC%20BerKata,mudah%20membagikan%20kebutuhannya%20dalam%20kata
[35] BANGOR, A.、KORTUM, P.T. 和 MILLER, J. (2009) 確定各個不锈钢分數的含義：增加形容詞評級量表。可用性研究雜誌，4 (3)，第 114-123 頁。
[36] INGLE B.R.（2013）設計思考簡介。請參閱：《企業家和小型企業的設計思維》，加州柏克萊：阿普雷斯，第 1-15 頁。DOI：10.1007/978-1-4302-6182-7_1。
[37] 菲格玛 (2024) 如何設計、調整和建造很重要。與菲格玛一起做。可從：

https://www.figma.com/
[38] 通訊社群 (2024) 亚克力的菲茨傑拉德金鑰。可從：https://www.communicationcommunity.com/fitzgerald-key-for-aac/