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Localized Text-Free User Interfaces

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ABSTRACT User interface is an essential element of an information system from the user perspective. The use of text in the user interface presents a challenge to some users, such as illiterate, elderly, non-local language speakers, or users with any disabilities. Numerous studies have proposed text-free user interfaces based on non-textual aids such as pictograms, audio, video, or specialized hardware. Such rich elements in the user interface have implications for an information system's storage and processing requirements. We propose using concept hierarchies to present a dynamic interface to a user based upon user characteristics. A drill-down approach may present more specific interface elements to a user, and a roll-up scheme can identify more generalized interface elements. The proposed scheme can be used to manage internal data of large user interfaces with a rich set of features more effectively as it is computationally inexpensive than sequential processing techniques. We also explore various physical and psychological characteristics of elements and evaluate user preference for them. The results of a survey of 200 respondents show that users consider the use of various colors, alignments, mental models, and look & feel to be essential criteria in interface design. We also conclude that size of interface elements and the use of characters for expressing emotions are significantly important characteristics in interface design. The future work will apply the proposed scheme to a full spectrum of applications ranging from enterprise systems to mobile applications.

INDEX TERMS Graphical user interface, software design, text-free user interfaces, user-centered design, user interface.

I. INTRODUCTION

Saudi Arabia is aggressively pursuing digitization of businesses and government systems. Vision 2030, the most recent initiative in this regard, endeavors to develop high-tech infrastructure, fully automated systems, futuristic services, and zero carbon emission in the newly developed mega-city Neom [1], [2]. Saudi Arabia aims to break into the top ten world countries in Global Competitive Index by 2030 [3]. One can foresee that this technology-driven agenda coupled with the profound global changes caused by the COVID-19 pandemic will result in more human-machine interaction for even routine tasks. The importance of user interface cannot be over-emphasized in an ecosystem designed primarily with robots and machines delivering most of the services to humans. The designers need to ensure that no group of users is at any disadvantage in benefiting from the available services.

The user interface is a core component of an information system that allows users to interact with the system [4]. Recent technological advancements have resulted in several innovative types of user interface styles such as natural language [5], voice [6], conversational [7], tangible [8], gesture [9], augmented reality [10], motion tracking [11] and zero-input [12] user interfaces. Although such interface styles aim to reduce the amount of text in user interfaces, they usually need specialized hardware. Also, most of these user interface styles are not suitable for general information system design. Hence, graphical user interface (GUI), an interface style primarily based on graphical components instead of text, remains the predominant information system interface design [13]. GUIs have varying amounts of text in addition to various forms of graphics. The presence of text in the user interface poses some challenges for some users, such as illiterate/semi-literate, elderly, and non-local-language speakers.

Illiteracy is an obvious barrier to effective use of user interface and thus an information system. The global community understands the importance of literacy in uplifting the communities. In 2015, all members states of the United Nations adopted the 2030 Agenda for Sustainable

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Development comprising 17 Sustainable Development Goals (SDGs), with SDG4 being related to education that targets to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [14]. Unfortunately, UNESCO's most recent progress review regarding SDG4 estimates that by 2030, about 225 million (14%) individuals aged 6 to 17 years will be illiterate [15]. It is to be noted that literacy rates are not uniform globally, and economically developing countries have higher illiteracy rates in general.

As stated earlier, semi-literate or illiterate users face difficulty using information systems that rely on a textual user interface. While illiteracy is the first barrier in using information systems, Eshet-Alkalai introduces the concept of "digital literacy" and argues that effective use of information systems requires a higher level of cognitive skills than mere ability to read the text [16]. Digital literacy encompasses the ability to process visual cues in the information systems (such as icons and other metaphors), the ability to synthesize the information from a variety of resources, the ability to process hyperlinked text, the ability to segregate credible and fake information, and the ability to collaborate and cooperate with other users in cyberspace. This concept of digital literacy provides additional dimensions to the commonly accepted notion of literacy and needs to be considered by interface designers.

Another class of users who have difficulty in using textual interfaces is elderly users. The cognitive abilities of elderly users may be affected by several factors such as dementia induced by cerebral atrophy or any disease, reduced motor skills, impaired vision, or a lack of focus. These factors contribute to a reduced ability to read, interpret and process text. Therefore, user interfaces relying primarily on text may not be very appealing for elderly users.

Non-local language speakers also face difficulty in using a system designed primarily for local users. Saudi Arabia relies heavily on foreign workforce. Although most of the information systems in Saudi Arabia are designed with bilingual user interfaces in Arabia and English languages, Arabic is the primary language for the interface, and imperfections exist in their English language counterparts. Additionally, most blue-collar workers cannot even understand the English language. Hence, these users may face difficulty in using information systems with text-based user interfaces.

Web-based systems offer an excellent user experience in terms of platform independence, user-friendliness, and version control. The World Wide Web Consortium (W3C) has developed Web Content Accessibility Guidelines (WCAG) 2.0 for designers and developers for designing accessible and inclusive interfaces. Various studies related to existing web-based systems have shown varying degrees of compliance with these guidelines [17]–[19]. Hence, there is a need to develop more inclusive interfaces accessible to all classes of users.

As all users cannot use textual user interfaces effectively, there is a need for improved interface styles. Interface designers have been using graphics, icons, and metaphors to minimize the amount of text in user interfaces since the invention of Sketchpad in 1963 [20]. More recently, the use of images, hand sketches, voice, video, and animations have been proposed by several researchers to design text-free user interfaces. Intuitively, the richer the interfaces are, the higher computational and storage requirements they have. This work explores the use of concept hierarchies to perfect such interface requirements. Based on the characteristics of a particular user, a drill-down or roll-up scheme can be used to present more generalized or more specialized interface elements, respectively. We have also studied various physical and psychological aspects of user interface design. Physical characteristics include characters for expressing various emotions, color, size, and alignment of interface elements. Psychological aspects comprise mental models and the look and feel of interface elements [21].

The rest of the paper is organized as follows. Section 2 presents a critical analysis of the most recent works in text-free user interface design and highlights their limitations. The proposed methodology is detailed in section 3. Section 4 presents experimental results, and the paper is concluded in Section 5.

II. RELATED WORK

Text is an essential medium of information exchange between individuals. Naturally, text was also the first tool used for designing user interfaces of computer systems. Early command-line user interfaces of computer systems relied on memorizing text commands [22]. As command-line interfaces required memorizing commands and typing commands was a time-consuming task, they were quickly replaced by graphical user interfaces (GUIs) [23], [24]. GUIs have proven to be more effective and user-friendly, especially for non-experts [25]–[27]. Although GUIs free the users from command memorization requirements, they are not entirely text-free and augment graphical components such as windows, icons, toolbars, wizards, ribbons, etc., with the text [28]. As argued in the previous section, the use of text in user interfaces may hamper certain individuals' ability to use information systems effectively. In the following, an overview and critical analysis of approaches used by various researchers to design text-free interfaces are presented.

The term "interaction design" refers to a user-centric approach for designing interactive products and systems [29]. A user-centered design is based on semiotics, Gestalt theory, and Gibson's affordance theory [30]. Semiotics is the study of signs and symbols [31]. It provides the basis of how we interpret and associate various symbols with actions or tasks. Semiotics is also influenced by socio-cultural norms and behaviors [32]. An effective interaction design rooted in semiotics exploits the most suitable signs, symbols, pictures, and graphics to convey the correct meaning to an end-user [33]. Gestalt theory is arguably a foundation stone in interaction design that provides the basis for visual perception of interaction elements [34]. Chang *et al.* suggest 11 laws from Gestalt theory that can be used in interaction design [35]. Gibson's affordance theory is another vital element in interaction design, stressing the need for intuitive design that minimizes a user's cognitive load in perceiving affordances [36], [37].

Several researchers have applied these theories and concepts to propose text-free user interface designs for several domains of life. Most of these solutions exploit audio, video, symbols, or pictures to develop such interfaces. Bao proposed a navigation system based on text-free maps that can be used by illiterate and non-local language speakers [38].

The proposed framework allows a user to search a place using text, audio, or symbols. Symbol search is limited to the type of place instead of a particular place. A usability evaluation study conducted on three types of users, including native English language speakers, non-English speakers, and illiterate users, showed a high System Usability Scale (SUS) score of illiterate users with map interface containing audio and symbols. The author proposes several enhancements to the proposal, such as more diversity in illiterate users selected for testing, considering the background of participants, showing the distance to destination, and a deeper study of illiterate users' perception of symbols. Medhi *et al.* developed an image processing tool to convert real images into abstract cartoon-like images that can be used in designing text-free interfaces [39]. A sample set of images are developed for healthcare application, but no usability testing is performed to measure the effectiveness of the proposed methodology. Jamali *et al.* proposed a metaphoric interface design for farmers in Malaysia [40]. However, the proposal covers only paddy farmers, and a thorough study is required to propose more metaphors and design more generalized text-free interfaces. Adama *et al.* studied existing banking systems in Nigeria and proposed an enhanced interface for novice users [41]. The authors exploit reduced scrolling, visual clues, voice support, and avoiding hierarchical menus to reduce the anxiety of novice users. However, the proposed interface depends on textual information. It is challenging to design completely text-free interfaces for a banking system, which relies mostly on numeric information. Baker *et al.* proposed voice-supported tactile graphics for blind and low vision users augmented with QR codes to read text inside these graphics [42]. The proposal has limited application as it cannot be generalized for designing text-free interfaces. Skarlatidou *et al.* developed a text-free interface for crowdsourced data gathering [43]. The proposed interface uses linear navigation and a tangible interface to achieve its goal. Islam *et al.* propose flashing graphics and audio for sales force automation tasks for semi-literate users [44]. Ilyas *et al.* propose to develop a sign language exploiting the knowledge gained through the use of daily life gadgets such as TV, remote control, and microwave [45]. This sign language can be used to design more familiar interfaces for users. Medhi *et al.* designed and evaluated text-free interfaces for rural healthcare and mobile banking domain [46]. However, the use of live operators suggests that the proposed solution is suitable only at a small scale and controlled environment. In another work, Medhi *et al.* studied the impact of limited formal education on hierarchical user interface navigation and found a strong correlation between literacy and the difficulty of using such interfaces [47]. Saleh and Sturm performed a similar study and evaluated the effect of literacy on the interpretation of symbols and signs in GUI [48]. Sunkari proposed INFOKIOSK, a smartphone app with a text-free interface that semi-literate and illiterate users can use to access informational videos [49]. The proposed interface allows to define the type of information needed through action images, provides a mouse-over navigation to the users, and comprehensive help videos on every application screen. Whittinghill and D. G. Herring compared two kinds of tutorials for a video game – with text annotation and video only [50]. The authors report that purely visio-spatial instructions also achieved at least the same results as with text annotation. The results need further investigation because of limited testing performed during the study. Baier developed a chatbot for a retail store using a two-mode cluster analysis of data matrix [51]. The proposed conversational interface was evaluated by 2,025 customers for various use cases and showed promising results. With the recent advancements in voice assistant technologies such as Microsoft Cortana, Apple Siri, Amazon Alexa, and Google Assistant [52], such conversational interfaces hold great potential for future applications. Zhou *et al.* studied the impact of emojis in instant messaging as a supporting element or as an alternative to text [53]. These findings can be used to design richer text-free user interfaces. Aguboshim and Miles propose several improvements in interfaces to encourage ATM usage in Nigeria, such as hand-drawn sketches, voice feedback in the user's language, and voice input [54]. The results of the study support findings of similar studies. Ahmed *et al.* proposed a set of icons to enhance Google App Store to make it more easily accessible to semi-literate and illiterate users [55]. Dhaygude and Chakraborty conducted telephonic interviews with several farmers to identify requirements of an interface design targeted towards illiterate users [56]. The authors argue that, in addition to the user experience, several soft factors like trust, connectedness, and family values play an important part in the adoption of digital platforms by illiterate people. Wołk *et al.* studied the issue of medical emergencies for people with special needs such as hearing/speech impairment, mental issues and inability to speak local language [57]. The authors propose text-free, voice-free pictogram-based interface that can be used by such people to express their medical condition or other needs. However, further studies are required to design such interfaces. Rodríguez *et al.* compared mobile and wearable interfaces for elderly users to report pain [58]. Chen and Liu studied the unique interface requirements of elderly users with dementia [59]. Using a case study of the microwave oven, the authors conclude that simplified interfaces are more effective for such users as they result in reduced cognitive load for elderly users. A similar study by Rot *et al.* also suggests that simpler interfaces are more effective for elderly users [60]. Dodd *et al.* provide an excellent review of unique requirements for interface requirements of elderly users [61].

Table 1 presents a summary of salient works related to text-free user interfaces. This table highlights the limitations of various application-centric solutions employing text-free interfaces. Different approaches from multiple domains have been covered; for instance, references [40], [56] refer to agriculture domain, references [39], [45], [46], [57], [58] present healthcare systems, references [54], [60] describe financial applications, references [45], [47], [51], [55], [60] relate to e-commerce type solutions, and references [38], [42], [50] show GUI based applications. The proposed solution overcomes the limitations of such applications having text-free interfaces. The main contribution of this research is to resolve the complexities involved in designing UI by employing concept hierarchy to bestow the users with the flexibility and convenience of understanding the UI design with drill-down and roll-up approaches.

III. METHODOLOGY

The proposed framework inspired by Gestalt theory (Figure 1) allows users to search a place using text, audio, or symbols. Symbol search is limited to the type of place instead of a particular place.

This research focused on two crucial aspects involved in designing localized text-free interfaces, (1) the essential design considerations based on the feedback of users from a variety of knowledge domains, and (2) efficient computational management of infographic/images/icons/vectors-inspired text-free user interfaces.

For design consideration, we considered the physical and psychological characteristics related to text-free design interfaces, as shown in Figure 2. The feedback of users has been presented in the section "Results and discussion." It is a natural physical phenomenon that the human brain discriminates objects based on color, size, alignment, and character [62]. Each physical characteristic can be described with concept hierarchy (as discussed in Figure 3). Color is a critical design consideration since the user age group significantly impacts preferred color parameters, i.e., depth, hue, saturation, and contrast [63], [64]. It is also noteworthy that dark objects have a better projection on lighter backgrounds and vice versa [65].

Similarly, the objects and the backgrounds having contract colors stand out excellently [66]. Similarly, the size of objects profoundly impacts users in the size concept hierarchy. Larger-sized items are more prominent and attractive than smaller-sized objects in the user interface. Aligning objects on user interface screens is vital since a consistent alignment style is more appealing than a random alignment of objects throughout the application/system design aspects. The character of objects emphasizes contrast concerning shapes. Commonly, elaborative shapes are more desired as compared to abstracted/generalized shapes [67]. Thus, a visual concept hierarchy may help in designing localized text-free interfaces.

Psychological characteristics are equally important aspects of text-free interface design. Mental models have an emotional involvement in the individual's thought process [68]. An effective design must consider an interface's overall look and feel, considering the users' opinion. For instance, an application's interface for kids' games is quite different from the one designed for the elders' hairstyle and stock market business application. Besides, it has been observed that giving several visual options, e.g., buttons, graphics, visual choices, may confuse the users in decision making. Thus, keeping the interface as simple as possible is suggested to avoid the considerable complexity of objects surrounding the entire visual panel and mainly hinder the right decision-making. This is also in line with laws of simplicity proposed by Gestalt's theory.

While a paradigm shift from the localized text-oriented interface to a text-free interface may result in convenience to the users, it may also result in an open challenge to manage a large quantity of infographics data, thus raising the computational complexities in terms of space and time requirements. Hence, to implement localized text-free interfaces, this research proposes the concept hierarchy in designing text-free interfaces. It is a common observation that we try to seek and reach information (intentionally or unintentionally) by drilling down from a holistic picture to its granular parts. Conversely, we also seek to roll up to reach the broader canvas from fine details. Such a natural concept hierarchy can significantly contribute to designing localized user-friendly text-free interfaces.

Figure 3 presents the general architecture to design the localized text-free interface with the concept hierarchy. Let us consider that a system or application is designed to provide two types of users' views to access the required information. In the case of drill-down, let us take an object $\mathbf{O}_1$ that presents the holistic view of application information at level "0". Object $\mathbf{O}_1$ segments into a list of sub-objects that describe the related information with three sub-objects represented by $\mathbf{O}_{1.1}$, $\mathbf{O}_{1.2}$, and $\mathbf{O}_{1.3}$. The user is interested in drilling granular information represented by a sub-object three at level two; we describe this sub-object with $\mathbf{O}_{2.1.2.1}$.

The system provides access to the user through text-free and object-based interaction to seek the required information.

The definition of an object of this type is system or application-specific and user-centered. The user can reach the desired item without having to read textual guidelines or external assistance.

On the other hand, regarding roll-up in concept hierarchy, let us assume that the user has viewed the required information associated with an object four at level "0" (represented by $\mathbf{O}_4$). The user is interested in seeking access to other information structured with the next level "1" (parent of the previous level) located with object $\mathbf{O}_{1.4.5}$. The system provides a way for the user to access $\mathbf{O}_{1.4.5}$ through $\mathbf{O}_4$. Generalizing the same concept, any information that resides at level two at the last object can be accessed through $\mathbf{O}_{2.1.2.4}$.

TABLE 1. Summary of proposals for text-free interface design.

Study	Application Domain	Target User Group	Technique	Limitations
[40]	Agriculture	Farmers	User-centered design Metaphors	A limited set of metaphors for paddy farmers only
[43]	Collaborative Data Collection	Low-literate users	Linear navigation structure and tangible interface	Small numbers of participants in the usability evaluation study
[56]	Agriculture	Illiterate	None	The study provides only requirements of an interface design for illiterate users
[55]	App store	Semi-literate users	Icons	Limited scope
[54]	ATM	Illiterate and semi-literate	Images, voice feedback in user's language, and hand-drawn sketches	Lack of a complete framework for developing text-free interfaces
[51]	Conversational commerce	General	Conversational user interface using two-mode cluster analysis of data matrix	Homogeneous rows and column clusters
[48]	General	Illiterate users	Signs	The study helps understand GUI for uneducated users but does not propose a complete framework for designing a text-free interface.
[50]	Video games	Gamers	Visio-spatial instructions	A small number of non-English users in evaluation Gamers' skill level may have a significant impact on results
[58]	Healthcare	Elderly	Mobile and wearable interfaces	Limited testing and inconvenient form factor of the proposed device
[59]	Home appliances	Elderly users with dementia	Simplified numeric interface	Testing was performed with a minimal number of users. The proposed interface is not entirely text-free.
[60]	Information aggregator	Elderly users	Enhanced web-based system	The proposed system relies heavily on text
[41]	Banking	Novice users	Voice support, graphical clues, avoiding scrolling, and hierarchical structures	The proposed interface is not entirely text-free
[57]	Emergency healthcare	Speech/hearing impaired, having mental issues, non-local language speakers	Pictograms	Needs more thorough usability evaluation to measure the effectiveness
[53]	Instant messaging	General users	Emojis	Limited application
[44]	Salesforce automation	Semi-literate people	Flashing icons and audio	No evaluation is performed. Comprehensive details of the proposed design are missing
[38]	Maps	Illiterate people and non-local-language speakers	Symbols and audio	Needs more diversified background of participants, search mechanism and voice recognition need improvement
[45]	Healthcare and e-commerce	Semi-literate and illiterate user	Icons inspired by daily life gadgets	A limited set of signs and no evaluation of proposed sign language
[42]	Tactile graphics	Blind and low vision users	Tactile Graphics with a Voice, QR codes	Limited application
[47]	Household items	Semi-literate and illiterate users	Graphics	Evaluation of hierarchical user interface navigation only
[46]	Rural healthcare and mobile banking	Novice and low-literacy users	Spoken dialog system and live operator	Poor scalability and controlled environment requirement
[49]	Information	Semi-literate and illiterate	Action images, mouse-over	No formal usability testing
[39]	Healthcare	Illiterate people	Cartoon-like images	No usability testing is performed to measure effectiveness

In the case of text-free interfaces that involve a more extensive set of objects at each level, the user can be assisted with a hierarchy of optional views of information to promptly access and revert between visual objects.

Assume we have developed a localized text-free user interface to present the medical-related information to illiterate or non-local language patients. The application guides the patients by employing an infographic or image concept

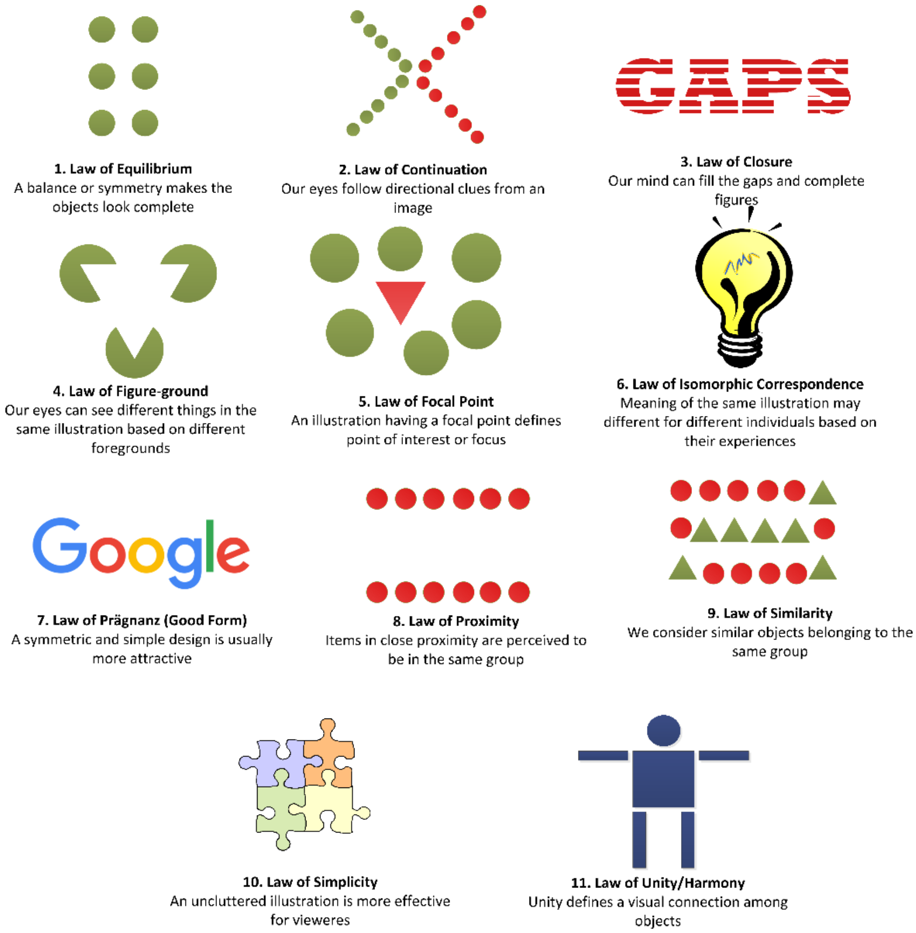

FIGURE 1. **Laws of interaction design inspired by the Gestalt theory.**

hierarchy, where the patient can drill down and roll up to seek the desired information.

Referring to Figure 4, suppose the patient clicks the hospital interface icon, the hospital icon at the patient side is usually an infographic type visual information, that once connected, leads the user to a set of graphical displays of medical departments, e.g., first aid, surgery, laboratory, and pharmacy. The further drill down presents the required information to the user. Since there has always been a tradeoff involved in developing such interfaces, the computational complexity in terms of space and processing time appears as a challenge for application developers to accommodate many icons/infographics/images.

Using concept hierarchy, the internal management of such interface data can be achieved by maintaining the data's corresponding structure. Such a notion splits the data into a scale of interface nodes where a single interface-node design is essential in its internal description. The structure may contain several other fields, i.e., name, ID, size, color, content description, and linking information to the next level or node. For a particular application, the total size of all nodes describes the aggregate size of individual nodes. Similarly, managing the same data and metadata in a list type structure is computationally expensive in linearly processing the information. Such type of hierarchical base orientation of interface data is well managed to employ conventional data mining or machine intelligence algorithms. In both text-free and text-oriented UI applications, the user guide helps users get familiar with the system and assists in viable usability aspects.

Figure 5 presents an example of the representation and storage hierarchy of data aligned with the concept hierarchy. Since a graphical interface may contain several objects that hold different features, managing such more extensive data with concept hierarchy is significant. Let us consider 900 localized text-free user interfaces. We have taken 450 user interfaces to display a hierarchical structure up to four levels. Referring to 1, the left and right interface data is managed by the nodes, starting from the root to the leaves. For each node, the following information is described; the node type, percentage of data to the left and right sub-trees, number of left or right interfaces with respect to the total number of interfaces, and the decision or concept hierarchy of child node with respect to its parent.

As shown in 2, the infographic numbers have been portrayed as hash keys of each interface as an internal representation of data. The application computes the probability of interfaces that should appear at the next level. The user

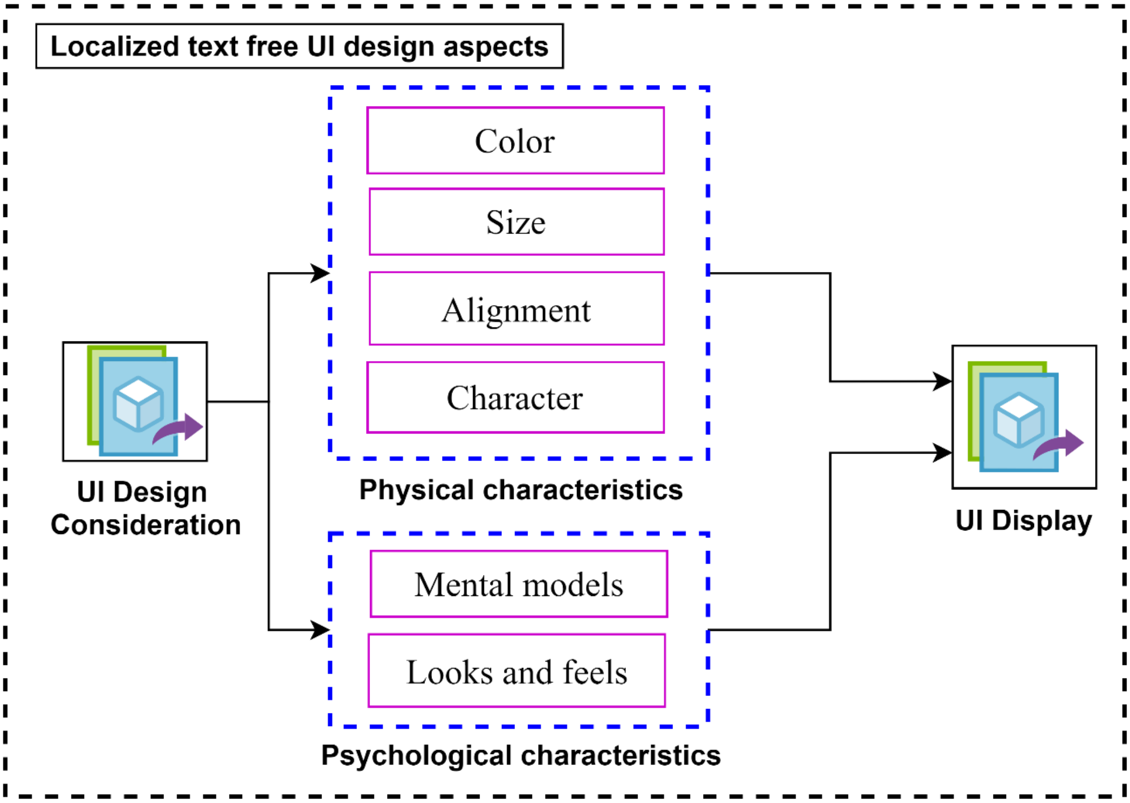

FIGURE 2. User-aspects for design consideration.

interfaces appear as a sequence of questions or options, and the next option appears as the action of its previous choice. The possibilities are the Boolean expressions in this particular case. Since this scenario is aligned with the concept hierarchy, the first option always appears at the hierarchical structure's root/start.

Hence, sequential or linear management of many text-free user interfaces is quite challenging and resource-constrained. Since each user interface of such a type is equipped with several parameters, i.e., name, ID, sequence number, color, size, shape, alignment, look and feel etc., the concept hierarchy is an effective solution for efficient management and presentation of visual objects for text-free interfaces.

IV. RESULTS AND DISCUSSION

This research introduced the concept "concept hierarchy for text-free UI design" and correlated it with users' experience by getting feedback on their experience against different applications they are using in their domains. It concluded that users' feedback on text-free interfaces with various UI characteristics supports the concept of this research. In addition, the literature review glimpses the limitations of text and text-free interfaces by realizing the limitations of exiting work resolved by the proposed concept and validated by the user experience.

To investigate the design considerations (as discussed in methodology) for developing localized text-free user interfaces, this research study analyzed the users' preferences presented in section 4.A. We explored 100 interfaces of different known and less-famous applications, systems, mobile applications, etc., to investigate the design aspects (presented in section 4.B). The research adopted random sampling to select respondents with different age groups and literacy levels. The dependent measure was users' ease of access/comfort/liking while using a UI-based application. The independent measures were the features or characteristics of UI, i.e., color, orientation, alignment, character, psychological aspects (look and feel), etc. The study preferred not to restrict users to some specific applications only. Instead, we left it to users/respondents to share their experience of using UI-based applications. The study performed ANOVA to measure the significance of findings by noticing a p-value <0.05 to ensure the achievement of a 95% confidential interval.

A. USERS' PREFERENCES OF LOCALIZED TEXT-FREE INTERFACES

The users are the real stakeholders once the application or the system is released for users' testing. This research study records and analyzes the users' feedback related to design aspects of the localized text-free interface. The study has surveyed 200 respondents from three broad domains, i.e., literate, semi-literate, and illiterate, with their distribution given in Table 2. The survey was conducted anonymously and confidentially (the authors adequately informed the respondents

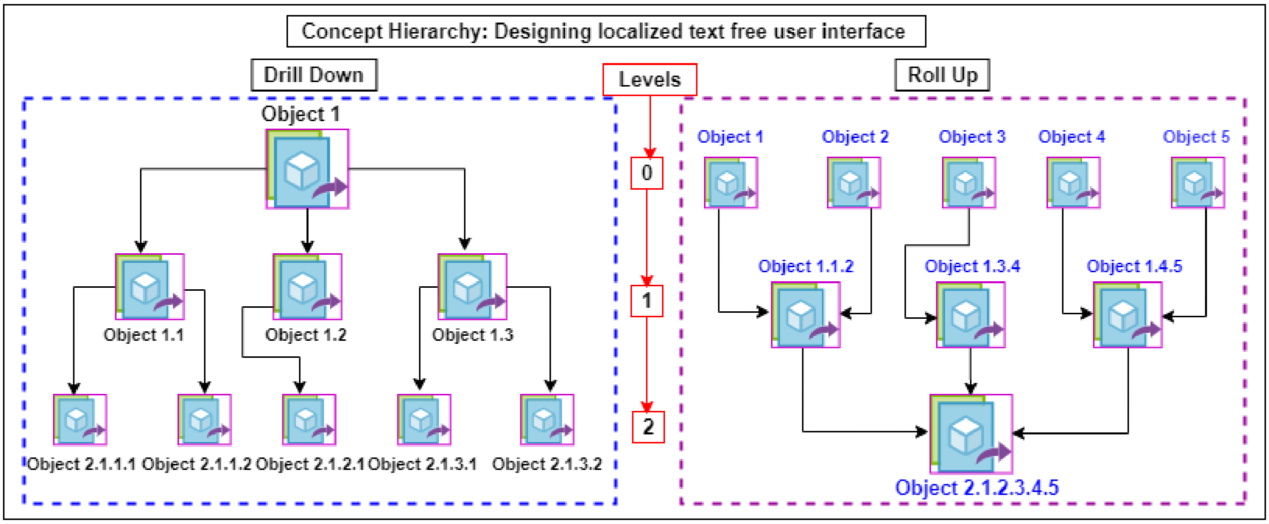

FIGURE 3. The general architecture of localized text-free interface with concept hierarchy.

FIGURE 4. Localized text free interface scenario of a patient-medical interface.

TABLE 2. Description of the study participants.

Age group	Female	Male	Illiterate	Literate	Semi-literate	Grand Total
15-30	33	21	21	27	6	54
31-50	43	55	12	53	33	98
51-65	24	24	9	23	16	48
Grand Total	100	100	42	103	55	200

and took their prior consent by ensuring not to reveal their feedback and other information for any purpose).

Figure 6 presents the outcomes of respondents relating to the significance of localized text-oriented interfaces. We can observe that most people from all age groups and all sex categories realize the localized text-oriented interfaces as insignificant. Besides, illiterate and semi-illiterate people also found it hard and challenging to operate applications and systems with text-based interfaces. Mostly the literature and young people favored having text-based user interfaces. The illiterate and semi-literate respondents preferred the text-based interface design as insignificant.

TABLE 3. Design aspects in the context of color and size.

	Object →	1	2	3	4	5	6	7	8	9	10	Grand Total
Color	Blue	4	2	5	1	3	2	1	2	2	1	23
	Clear	1		4		3	2	2	1	3	2	18
	Purple	1	1	2		2	1				3	10
	Rainbow	2		3	1	3	5	2		1	2	19
	Red	5	1	4	4	3	3		2	4	4	30
	Grand Total	13	4	18	6	14	13	5	5	10	12	100
Size	Large	1		4		3	2	2	1	3	2	18
	Medium	4	2	5	1	3	2	1	2	2	1	23
	Small	2		3	1	3	5	2		1	2	19
	Very Large	5	1	4	4	3	3		2	4	4	30
	Very Small	1	1	2		2	1				3	10
	Grand Total	13	4	18	6	14	13	5	5	10	12	100

We have chosen three broad age groups of respondents: people between 15 to 30 years, 31 to 50 years, and 51 to 65 years. Forty-two respondents were utterly illiterate, 55 semi-illiterate, and 103 were recorded as literate. The cross-tabulation of data represents 54 respondents in the age group of 15-30 years, 98 respondents in the age group of 31-50 years, while 48 respondents were noticed from the age group of 51-65. These statistics show that about 50% of the total respondents are literate, and they are young people between 31 to 50 years of age. Besides, 50% of respondents were females, with about 50% of the same young age group.

Figure 7 presents the outcomes recorded as the response of people related to designing text-free interfaces. We can observe that most people find the localized text-free interface design as significant and user-friendly with red and yellow

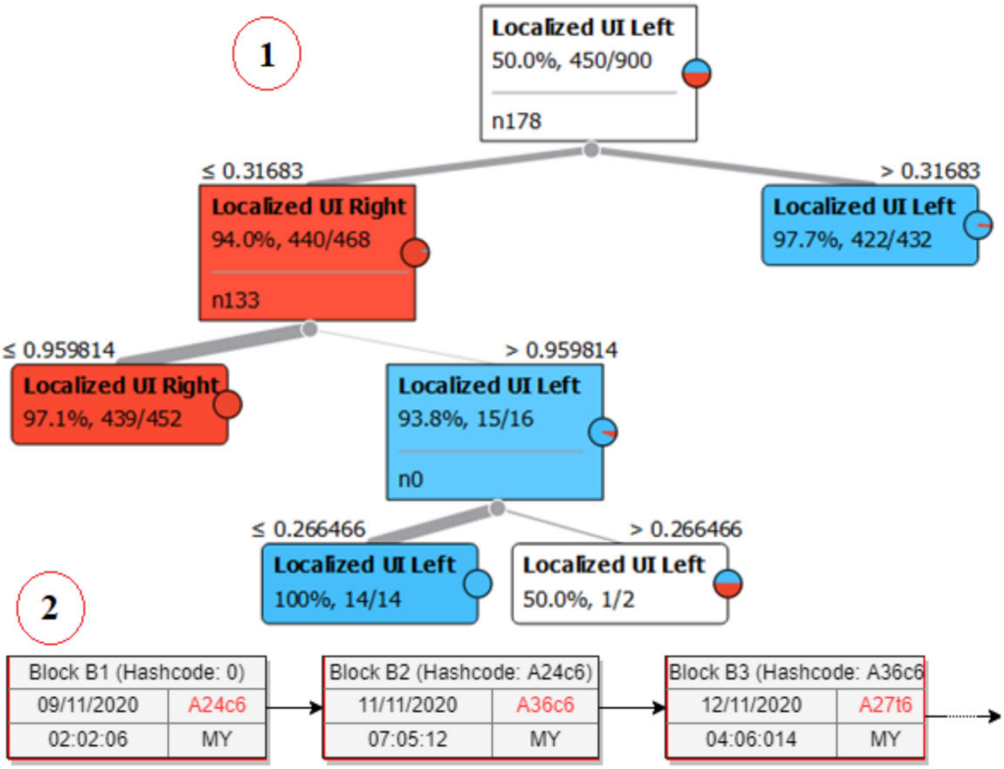

FIGURE 5. Representation and storage hierarchy of data aligned with concept hierarchy.

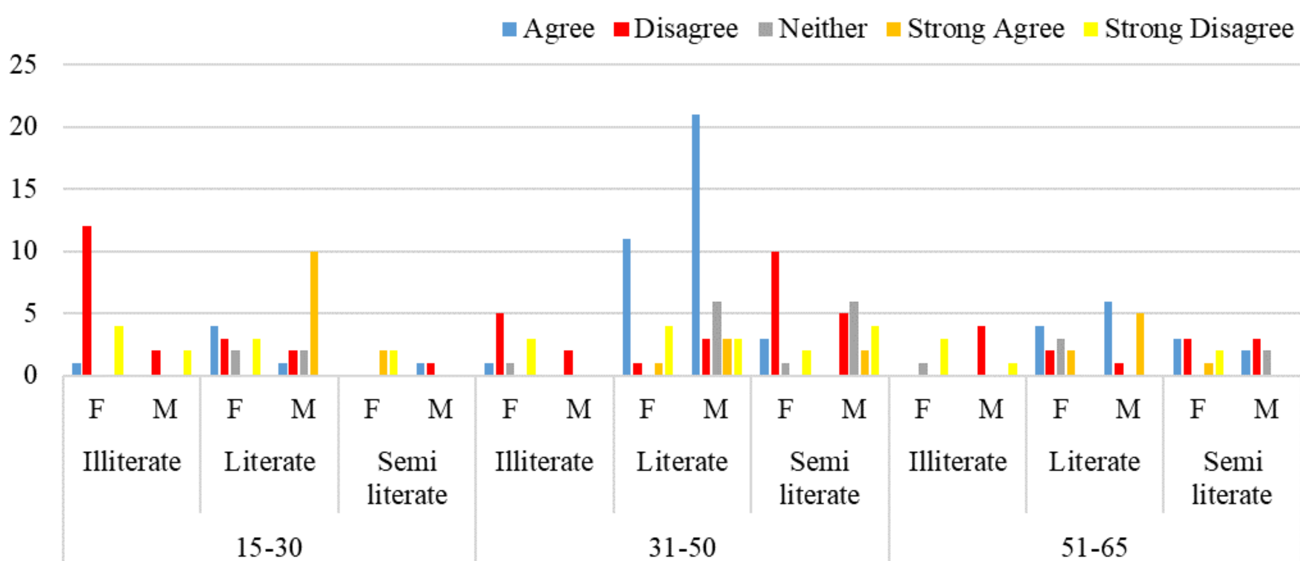

FIGURE 6. Feedback of respondents related to localized text-based interfaces.

bars. Illiterate and semi-literate people mostly showed interest in text-free interface design since operating applications with localized textual interfaces becomes challenging.

Figure 8 describes the respondents' opinions about the contribution of different color values for designing text-free user interfaces. We can observe that most of the respondents have given a favorable vote towards including colored patterns of different types while designing a graphical user interface. Like the previously analyzed feedback, the young and literate users favor adopting various color schemes in design-related matters.

Figure 9 shows the impact of the size of the interface and graphical objects placed on the user interface panel. Contrary to the previous feedback, we observe that most of

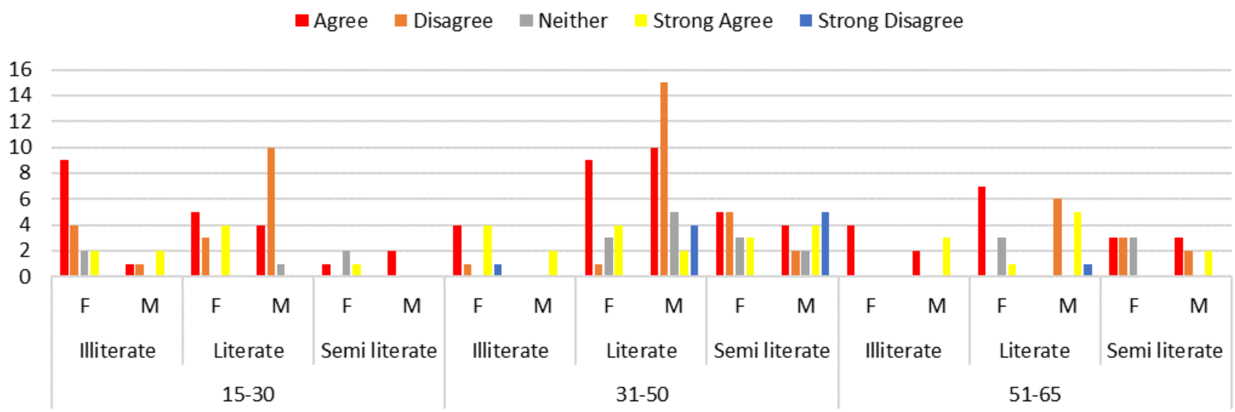

FIGURE 7. Respondents feedback for localized text free interface design.

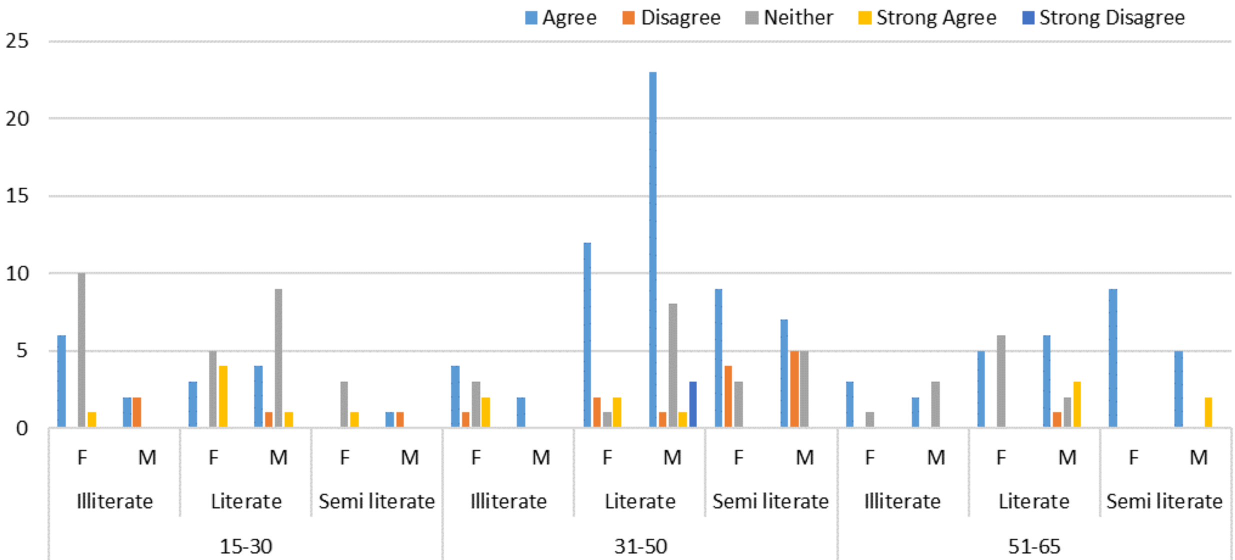

FIGURE 8. Feedback related to the significance of color in user interface design.

the responses are neutral. It depicts that almost 50% of users do not consider the size significant towards an effective user interface design. On average, 50% of people equally favored that the size of interface and objects matter from the design perspective. Here, we can also notice that young and literate respondents have either voted in favor of size as a significant measure or voted neutral.

Figure 10 shows the importance of the alignment of graphical objects on the design panel. We can observe that most of the respondents favored considering the alignment perspective as an essential aspect of developing an excellent user interface. Hence, it can be viably declared that the alignment aspect is equally important in localized text-free user interface design.

Figure 11 provides an overview of the importance of character in design aspects from the respondents' perspective. Contrary to the previous analysis, we found that most people did not prefer the character to be considered a good design. The people's neutral opinions might include the correct definition of character while creating the user interface. Both literature and illiterate respondents could not give feedback as positive or negative in this context.

TABLE 4. Design aspects in the context of alignment and character.

	Object →	1	2	3	4	5	6	7	8	9	10	Grand Total
Alignment	Center	8	2	9	2	5	3	2	3	3	6	43
	Default			3	2	1	3	1	1	3		14
	Left	4	2	2	1	7	4	1	1	3	4	29
	Right	1		4	1	1	3	1		1	2	14
	Grand Total	13	4	18	6	14	13	5	5	10	12	100
Character	Funny	4		6	1	7	5	2	3	2	5	35
	Moderate	6	1	7	3	5	6	3	2	6	5	44
	Serious	3	3	5	2	2	2			2	2	21
	Grand Total	13	4	18	6	14	13	5	5	10	12	100

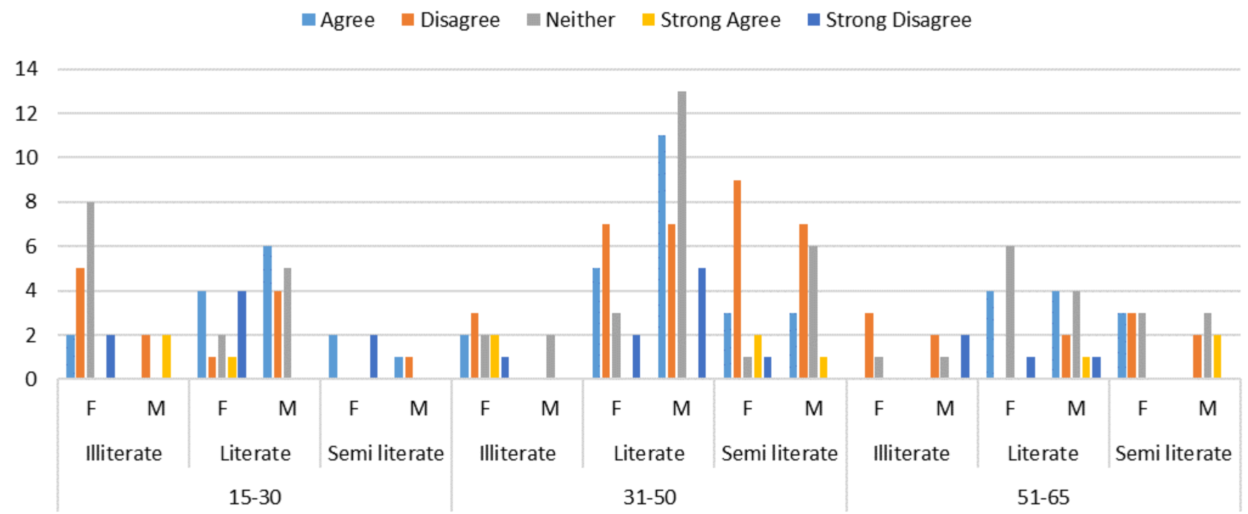

FIGURE 9. Impact of the size of the interface.

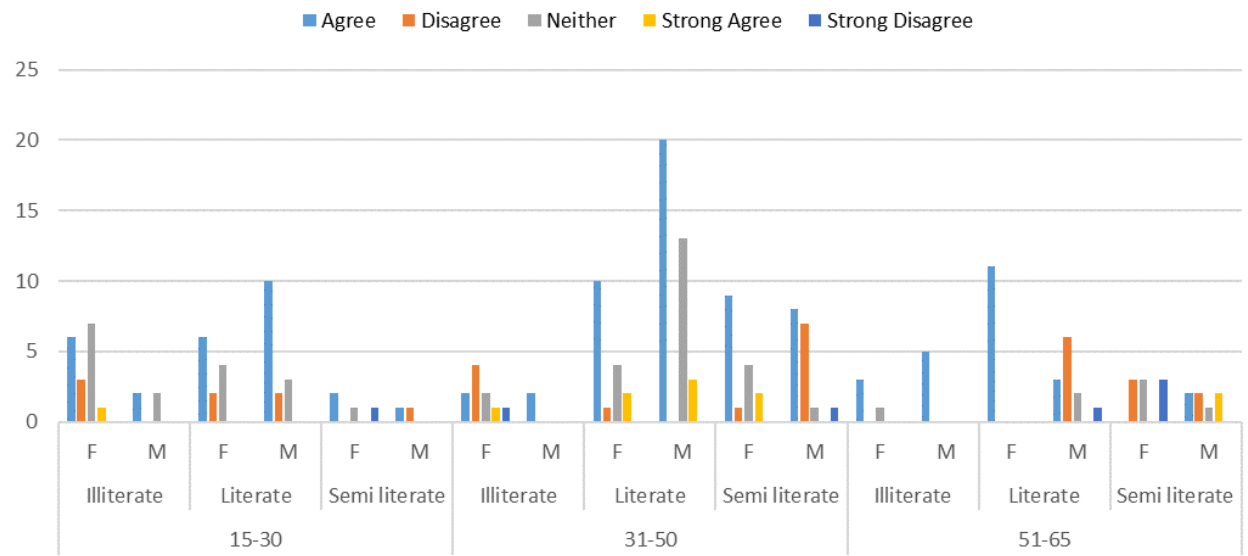

FIGURE 10. Role of alignment in the design prospective.

Figure 12 highlights the feedback related to the inclusion of mental modes in design aspects. It is prominent to analyze that most of the respondents agreed that UI design developers should consider the elements of cognitive ways.

Figure 13 presents participants' responses to the importance of considering the look and feel aspect in designing localized text-free interfaces. We can notice that most respondents considered look and feel like an essential component of the user design. Similar to the previous trend found in the statistical analysis of data, the young and literature people have favored this aspect of the user interface.

The survey findings potentially express the significance of considering different user interface components in developing localized text-free user interfaces. It is a natural physical phenomenon that the human brain discriminates objects based on color, size, alignment, and character. Each of such physical characteristics can be described with concept hierarchy. The psychological factors are equally important in text-free UI design. Additionally, mental models have an emotional involvement in the individual's thought process.

B. RESEARCH INVESTIGATION OF EXISTING USER INTERFACES OF VARIOUS APPLICATIONS

We investigated the user interfaces of several applications and recorded the design considerations adopted by the application.

Table 3 summarizes different colors and sizes of graphical objects adopted in various applications' interface designs. It can be observed that red and blue colors have been widely

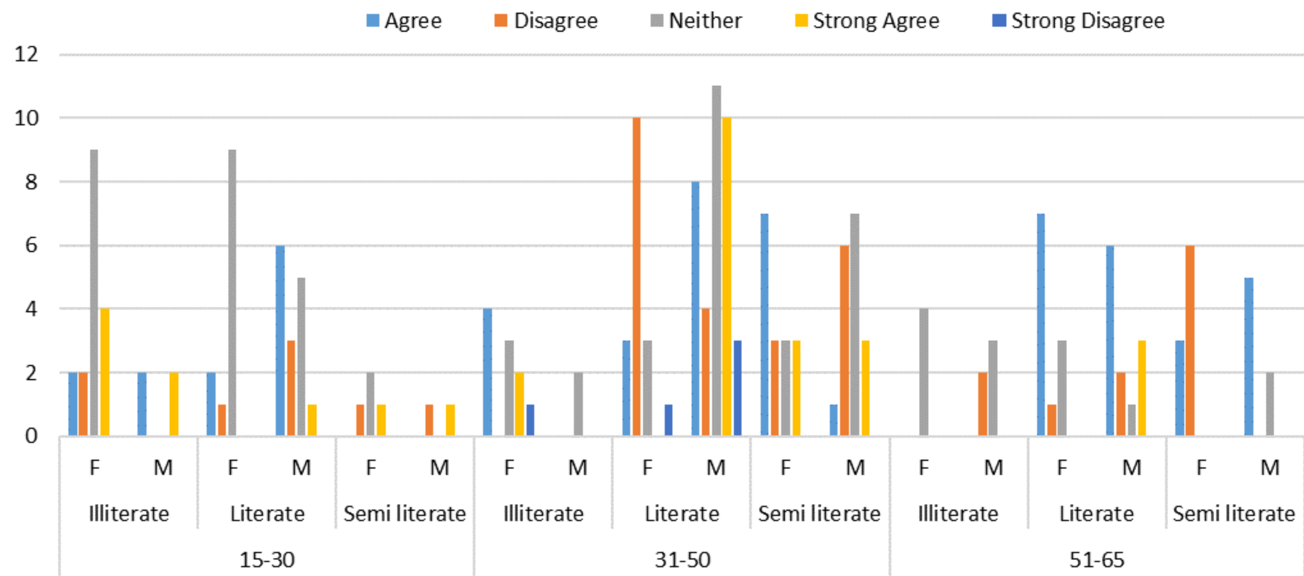

FIGURE 11. The aspect of considering character in designing the interface.

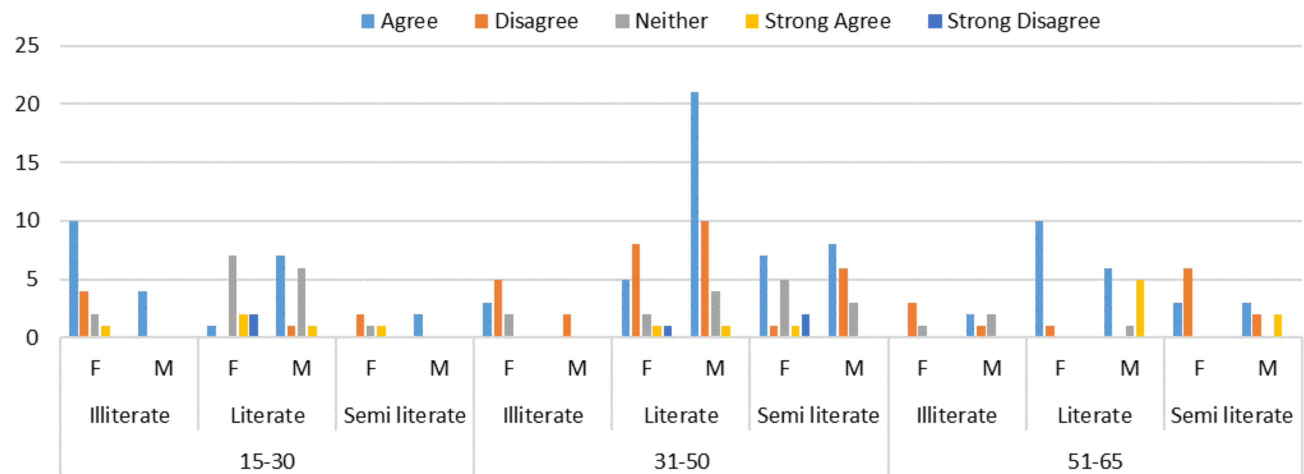

FIGURE 12. Consideration of mental modes in user interface design.

preferred in interface design. The rainbow and transparent colors have similar considerations. However, the purple color has been used relatively less commonly. Regarding the sizes of different objects in various interface screens, the larger-sized items have been given preferences. Medium-sized objects have also been employed with a proportion of almost 25%. The small-sized objects were found to be significantly less common in designing user interfaces.

The design consideration for alignment and character of different objects have been described in Table 4. A significant proportion of applications adopted center-alignment of objects, i.e., 43%, while left-alignment was also preferred with a significantly higher ratio, i.e., 29%. In addition, the right-alignment and default-alignment of objects were found to be less commonly employed for designing user interfaces. Besides, moderate character consideration was made for a larger set of objects, i.e., 44%, followed by more serious character interfaces, i.e., 21%. In comparison, the percentage of funny characters, primarily used in kids' applications, was recorded as 35%.

Table 5 summarizes design aspects in the context of mental models and look and feel elements. Most applications adopted default mental models, followed by fixed-type models. We observed that these models were employed based on the prior users' choices. The adaptive mental models were realized as 29% of the total proportion of mental models. Since the design of applications, once developed and delivered, is very hard to change, most applications stick with

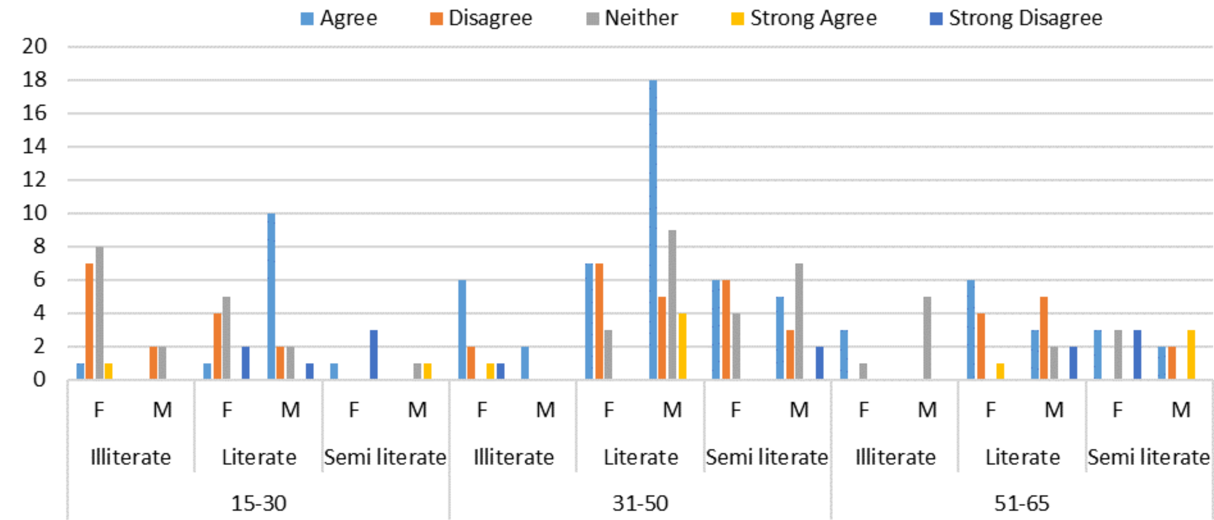

FIGURE 13. Significance of look and feel.

TABLE 5. Design aspects in the context of mental models and look & feel.

	Object →	1	2	3	4	5	6	7	8	9	10	Grand Total
Mental Models	Adaptive	2	2	3		5	7	2	3	2	3	29
	Default	5	1	9	5	6	3	2		2	3	36
	Fixed	6	1	6	1	3	3	1	2	6	6	35
	Grand Total	13	4	18	6	14	13	5	5	10	12	100
Look & Feel	Cool	2	1	5	1	3	6	2	2	1	5	28
	Hot	4	3	6		5	4	2	1	3	2	30
	Medium	7		7	5	6	3	1	2	6	5	42
	Grand Total	13	4	18	6	14	13	5	5	10	12	100

either default or fixed choices of mental models. Similarly, the medium look and feel were preferred by the users in 42% of applications. The hot and cool type look and feel also had similar preferences in the design aspects.

V. CONCLUSION

Based on a larger domain of users' preferences and the researchers' investigation of existing design aspects of various applications, a strong need for localized text-free interfaces has been realized. This research proposed the concept hierarchy in designing text-free interfaces to cover the holistic and granular aspects. The physical and psychological characteristics related to text-free design interfaces are essential to design considerations. The appealing UI designs require objects with necessary disparities based on color, size, alignment, character, mental models, and look and feel characteristics. We have shown that the internal management of data related to large text-free interfaces can be effectively maintained by segmenting the data into a hierarchy of interface nodes. This scheme is computationally inexpensive compared to sequential processing data of text-free interfaces in managing graphical objects with richer features. The future work will focus on applying this scheme to a range of software programs for various applications. We plan to implement the proposed scheme on large enterprise systems, web-based systems, and mobile applications.

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