International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Ingénierie des Systèmes d'Information
Vol. 28, No. 6, December, 2023, pp. 1709-1717
Journal homepage: http://iieta.org/journals/isi

Enhancing Human-Computer Interaction: A Comprehensive Analysis of Assistive Virtual Keyboard Technologies

Amal Hameed Khaleel[1*], Thekra HayderAli Abbas[2], Abdul-Wahab Sami Ibrahim[2]

[1] Department of Computer Science, Basrah University, Basrah 61001, Iraq
[2] Department of Computer Science, Mustansiriyah University, Baghdad 10001, Iraq

Corresponding Author Email: amal.khaleel@uobasrah.edu.iq

https://doi.org/10.18280/isi.280630

Received: 12 August 2023
Revised: 31 October 2023
Accepted: 4 December 2023
Available online: 23 December 2023

Keywords:
computer vision, eye-gazing, eye-tracking, human-computer interaction, virtual keyboard layout

ABSTRACT

In the realm of assistive technology, significant advancements have been made to facilitate the interaction of individuals with physical impairments with information technology. This study presents a comprehensive analysis of recent methodologies developed for remote computer interaction and text input, predominantly focusing on individuals with disabilities. Emphasis has been placed on compiling and comparing a diverse array of algorithms that contribute to the design of compact, adaptable, and optimized virtual keyboards. Through meticulous research, it has been observed that adaptable keyboard designs demonstrate superior effectiveness in catering to the diverse needs of users. The exploration extends to the domain of computer vision and human-computer interaction, highlighting their pivotal role in the advancement of assisted virtual keyboard technologies. The virtual keyboard, recognized as a predominant computer input method, has undergone significant evolution, especially in facilitating hands-free text entry. This evolution is largely attributed to the development and application of various eye-tracking methodologies. The paper concludes by presenting an insightful discourse on potential directions for future research in this field. The study's findings underscore the transformative impact of these technologies in enhancing communication and access to digital platforms for individuals with physical disabilities.

1. INTRODUCTION

The advancement of computer vision research endeavors to develop electronic devices capable of analyzing and understanding visual data. It has been established that through computer vision, computers gain the capability to perceive their environment and identify objects [1, 2]. This technology offers a foundation for proposing adaptable solutions aimed at enhancing the independence of individuals with disabilities, particularly in their daily living, professional engagement, and communication [3].

This study's principal aim is to examine recent methodologies employed for remote computer interaction and textual input. The focus is on contrasting various strategies and their outcomes, leading to a compilation of algorithms for creating virtual keyboards that are compact, adaptable, and optimized.

Recent developments in natural user interface design have involved exploring various modalities for intuitive computer interaction. The selection of communication devices is largely influenced by the nature of the user's disability [4]. Virtual keyboards serve as a significant tool for both able-bodied and disabled users [5]. Evaluation of patients with disabilities often involves analyzing their head and eye movements, speech, and brain signal detection, such as through electroencephalograms [6, 7].

Keyboards, including virtual ones, are recognized as one of the most efficient means for text input and editing. The layout of these keyboards plays a crucial role in mitigating musculoskeletal issues and influences typing speed [8]. Keyboard layout refers to the arrangement of numbers, letters, and punctuation on a keyboard. The primary objectives in designing new keyboard layouts are to minimize repetitive strain injuries and enhance typing speed [9].

The structure of this study is organized as follows: Section 2 provides a summary of related research, emphasizing keyboards with optimal layouts. Section 3 introduces the methodology and simulated proposed designs for virtual keyboards. Section 4 discusses the findings from the performance assessment and system accessibility evaluations. Finally, the conclusion synthesizes these insights.

2. RELATED WORKS

Recent scholarly discourse on virtual keyboards has predominantly concentrated on input system optimization strategies. It has been observed that a considerable portion of this research has prioritized enhancing system performance, which involves augmenting text entry rates and reducing error margins, often at the expense of exploring multi-modal approaches. In an effort to elucidate the advancements in visual input systems, particularly in the realm of virtual keyboards, the existing literature has been segmented into three distinct categories as follows.

2.1 Studies on utilizing body gestures

In the domain of alternative input methods, several studies have explored the utilization of body gestures, focusing particularly on hand and tongue movements, as a means to facilitate user interaction with virtual keyboards. One notable approach involves leveraging the agility and precision of the tongue as a substitute for hand-based control over mouse and keyboard functions. Struijk et al. [10] proposed an inductive intraoral tongue interface comprising 18 sensors, designed to control an assistive robotic arm. This interface includes an external central unit that receives data from the tongue-based input and functions as a wireless mouse or keyboard when connected to a computer.

Additionally, Hedeshy et al. [11] introduced an innovative hands-free text input method through visual cues and humming. They developed and evaluated two design options: HumHum and Hummer. In the former, text input is initiated and concluded with brief hums marking each syllable, while the latter interprets continuous humming as a marker for the start and end of a word. This method utilized an RDE NT-USB microphone for capturing the humming sounds and a Tobii 4C eye-tracker with a 90 Hz tracking frequency for gaze detection.

Conversely, Tathe et al. [12] proposed a system aimed at identifying hand gestures to emulate mouse and keyboard functionalities. This system included the use of various hand gestures to manipulate mouse cursor movements and emulate clicking actions. Specifically, it explored the feasibility of using a single-finger gesture for letter selection on the keyboard and a four-finger motion for navigational purposes. The pupil tracking technique employed was derived from the TrackEye software developed by Zafer Savas.

2.2 Studies on eye-tracking techniques

Exploration in the field of eye-tracking techniques has yielded various methodologies for enhancing gaze-based interaction with virtual keyboards. The subsequent analysis highlights key contributions in this domain:

Meena et al. [4] proposed an array of dwell-free and dwell-based approaches, incorporating multisensory elements, for a gaze-based keyboard simulation tailored to the Hindi language. This approach allows for item selection via gaze-tracking, with options such as asynchronous surface electromyography, soft switches, or gesture recognition for making selections. Furthermore, a probabilistic model adjusts dwell time based on the likelihood of letter selection informed by previous choices [13]. Advancements in machine learning have facilitated the development of the i-Riter [14], designed to enable individuals with paralysis to type on a screen using only their gaze. Lystbµk et al. [6] introduced a gaze-based virtual keyboard allowing direct access to letters with a single command and proposed a USB mouse switch for left-click functions.

Cecotti et al. [15] devised a simulated keyboard with ten primary commands, correlating to essential keystrokes and enabling the creation of 74 different characters using an eye-tracker. This interface reduces the spatial proximity of commands within the graphical user interface (GUI) and operates based on a tree selection mechanism, allowing letter selection from two tiers with minimal commands.

The critical aspect of gaze-tracking lies in the accurate determination of pupil or iris position. Iris recognition is crucial in various applications, with several regression-based methods available for gaze position estimation post-iris center identification [16]. Most eye-tracking techniques involve iris recognition challenges associated with circle analysis [17]. A machine-learning approach for eye identification in a dynamic environment, utilizing a Viola-Jones face detector [18]. The WiViK [19] represents a virtual keyboard offering standard QWERTY functionality, operated via an eye-gaze pointing device. Hearty Ladder [20] developed a Japanese syllabary eye-gaze-controlled typing system, considering the frequency of Japanese vowels in the Roman alphabet for designing its key input interface.

Cecotti et al. [21] introduced a novel multimodal, multiscript gaze-based virtual keyboard, adaptable for Bangla, Latin, or Devanagari scripts. This GUI can be modified to suit different scripts within the same layout, with compatibility for mouse, touch display, mouth switch, and gaze recognition inputs. The keyboard features 40 keys, including an eraser, English text types, mathematical numbers, and various Latin symbols, along with a spacebar for form typing and textual suggestions at the top.

Lastly, Islam et al. [5] presented an eye gaze-controlled on-screen keyboard, operable through eye blinks. This keyboard includes 40 keys for English fonts, a delete key, numeric, and various Latin symbols, with keys illuminated sequentially or in a counterclockwise fashion.

2.3 Studies on keyboard layout algorithms

This segment of the literature review delves into the research focused on keyboard layout algorithms, with an aim to enhance typing speed and accuracy. The following studies are noteworthy in this context:

2.3.1 Dwell-free gaze-controlled typing systems

A novel approach integrating a dwell-free method for intermediate letters and a dwell-time strategy for initiating and concluding words was introduced by Cheat and Wongsaisuwan [22]. This method employs the concept of edit distance, which is calculated based on the replacement cost and influenced by the weights of adjacent characters. This calculation aims to determine the optimal weight that ensures high accuracy in typing. Additionally, the study encompasses an array of previous dwell-free gaze-controlled typing systems. These include EyePoint [23], Gazing with pEyes [24], StarGazer [25], Eyeboard [26], Eyeboard++ [27], Filteryedping [28], and EyeSwipe [29]. Each of these systems represents a unique contribution to the field, demonstrating the diverse approaches and innovations in dwell-free gaze-controlled typing technologies.

2.3.2 Dwell-duration gaze-controlled typing systems

The following studies have focused on dwell-duration gaze-controlled typing systems, which aim to optimize key selection efficiency and accuracy:

A study introduced a method for dynamically adjusting key dwell duration based on key placement and selection [30]. Subsequently, Tamilselvi and Sarguna [3] developed a multimodal virtual keyboard with 30 characters and evaluated performance variations under three conditions: direct eye-tracking for command selection, mouse-based target pointing, and switch-based selection.

Cheat and Wongsaisuwan [31] proposed an on-screen keyboard using the Tobii EyeX Controller. Their method integrated dwell-free and dwell-time strategies in a swipe gaze-based keyboard, incorporating a storage system for previously typed words to prioritize intended phrases. The initial and final letters are activated using dwell-time, switching to dwell-free mode thereafter.

Pedrosa et al. [32] described cascading dwell gaze-typing, dynamically reducing dwell time for likely keys based on their probability of being selected next and their position on the keyboard.

Meena et al. [33] presented a method for optimizing the arrangement of displayed objects in a gaze-controlled, tree-based panel selection infrastructure. This Hindi-specific virtual keyboard was designed around a menu with ten commands, accessing 88 character sets and various text editing functions.

Pradeepmon et al. [34] introduced S-finger typing layouts, employing quadratic assignment project (QAP) optimization algorithms for creating keyboard layouts optimized for typing speed and finger mobility. Sandnes et al. [35] recommended increasing dwell time for the first element in scan sequences to reduce input errors on scanning keyboards.

The C-QWERTY arrangement [36] was designed for circular smartwatches, featuring keys in a circular layout along the screen edge, supporting both finger touch and finger interaction. Whittington and Dogan [37] proposed the Smart Power Chair (SoS), which employed an appropriate set of independent and interoperable technologies that were networked over time to meet the specified overall aim of improving the quality of life for individuals with disabilities.

Herthel and Subramanian [38] worked on optimal single-finger keyboard layouts for mobile phones. Kumar et al. [39] introduced TAGSwipe, a bi-modal swiping method combining touch and gaze motions for word selection on virtual keyboards.

Onsorodi and Korhan [8] used a genetic algorithm to design an ergonomic keyboard, reducing typing time and fatigue by considering the frequency of the most commonly used English words. The T18 keyboard by De Rosa et al. [40], inspired by the T9 system, features 18 keys in a QWERTY pattern, selecting dictionary-based characters for each keypress. Benabid Najjar et al. [41] optimized key placement for Arabic keyboards using eye-tracking, focusing on minimizing overall travel distance while typing specific sentences.

A Japanese syllabary interface [42] organized letters on a pentagonal chart, considering the consonant-vowel structure of the Japanese sound system. Alshudukhi and Alshaibani [9] proposed an optimized Arabic keyboard layout to reduce typing time using statistical measures. Caligari et al. [43] investigated the impact of age on eye-typing capabilities, finding a decline in typing speed and an increase in errors with age. Finally, Mohsin and Oday [44] utilized a virtual keyboard as a defense against attacks, transforming Arabic or English letters from ASCOII values to a point-based system.

2.3.3 Modern algorithms-controlled typing systems

This section explores contemporary approaches in typing systems, emphasizing the integration of modern algorithms to enhance user experience and accuracy:

Shen et al. [45] introduced Adapti-Keyboard, a mid-air gesture keyboard optimized for augmented reality (AR) environments. This system focuses on improving user experience by addressing articulation inaccuracy. Adapti-Keyboard employs an adaptable layout size optimization, allowing for a more versatile keyboard with an expanded design and operating area. This customization considers users' motor skills and preferences, facilitating a more effective adjustment of the keyboard's layout to suit individual user needs.

In contrast, Turner et al. [46] investigated the usability and typing performance of two QWERTY keyboard layouts on different smartphone sizes. Their findings indicated a slower typing speed with a curved keyboard on a smaller phone (15 WPM) and a faster rate with a standard keyboard on a larger phone (24 WPM). The curved keyboard consistently resulted in higher error rates, regardless of phone size. Nivasch and Azaria [47] developed the MKLOGA method, which combines deep learning with a genetic algorithm-based approach to enhance keyboard layouts. This method significantly improves the efficiency of genetic algorithms through an advanced crossover process. MKLOGA demonstrates superiority over previous layouts and shows potential for designing layouts in languages other than English.

Khan and Deb [48] utilized the NSGA-II method to generate a Pareto collection of keyboard layouts, ranging from the most economical to the most ergonomically advantageous. This collection can facilitate a gradual transition from the prevalent QWERTY layout to configurations better suited for specific applications. The NSGA-II algorithm, paired with an EMO approach, optimizes keyboard layout to maximize typing efficiency using a distance metric.

Additionally, Kafaee et al. [49] examined the evolution of keyboard layout design, applying the Collingridge dilemma to the transition from typewriters to brain-computer interfaces. This study provides a quantitative analysis of the dilemma, offering a deeper understanding of the challenges in technological evolution. The investigation into the QWERTY keyboard underscores the potential of human-technology co-construction theory in comprehending technological advancements.

In summary, research in keyboard layout design has varied in focus, from eye-tracking and mid-air gestures to advanced algorithmic solutions. While most studies concentrated on the English language, significant efforts were made to develop keyboards in other languages, including Arabic [9], Hindi [4], Latin, Bangla, Devanagari [5], Japanese [20], and others, reflecting the global application of these technologies.

3. METHODOLOGIES

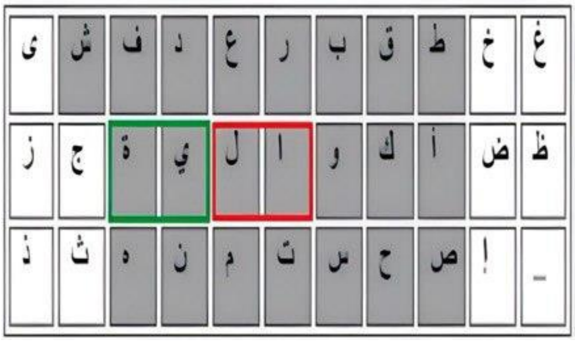
The methodology employed in controlling virtual keyboard functionalities commences with the application of face detection software, focusing on eye location. In certain scenarios, detection of hand and lip movements is also integrated. The initial step involves preprocessing the image or video feed from the camera, which is subsequently converted into a grayscale image.

This grayscale image undergoes further processing, being transformed into a bitmap format. It is then classified using various techniques including Haar-cascade, MAR algorithm, support vector machine, and Eye Detection Eye-Aspect-Ratio (EAR) [1, 50], among others.

(a) QWERTY keyboard configuration (fitness: 178779) [49]

(b) GA-optimized keyboard configuration (fitness: 76933) [49]

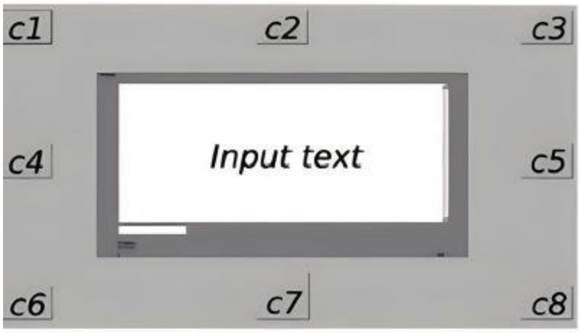
Figure 1. The layout of recent keyboards



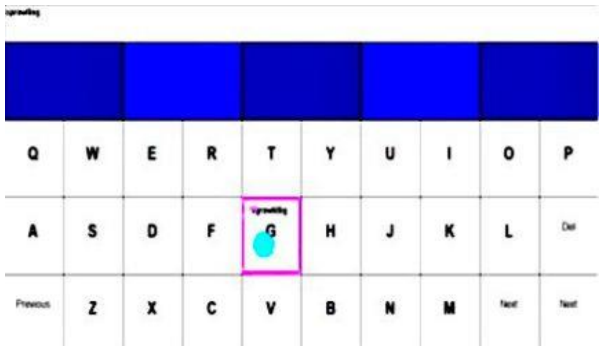
(a) The experimental interface of a virtual Arabic keyboard [41]

(b) The experimental interface of improved Arabic keyboard [9]

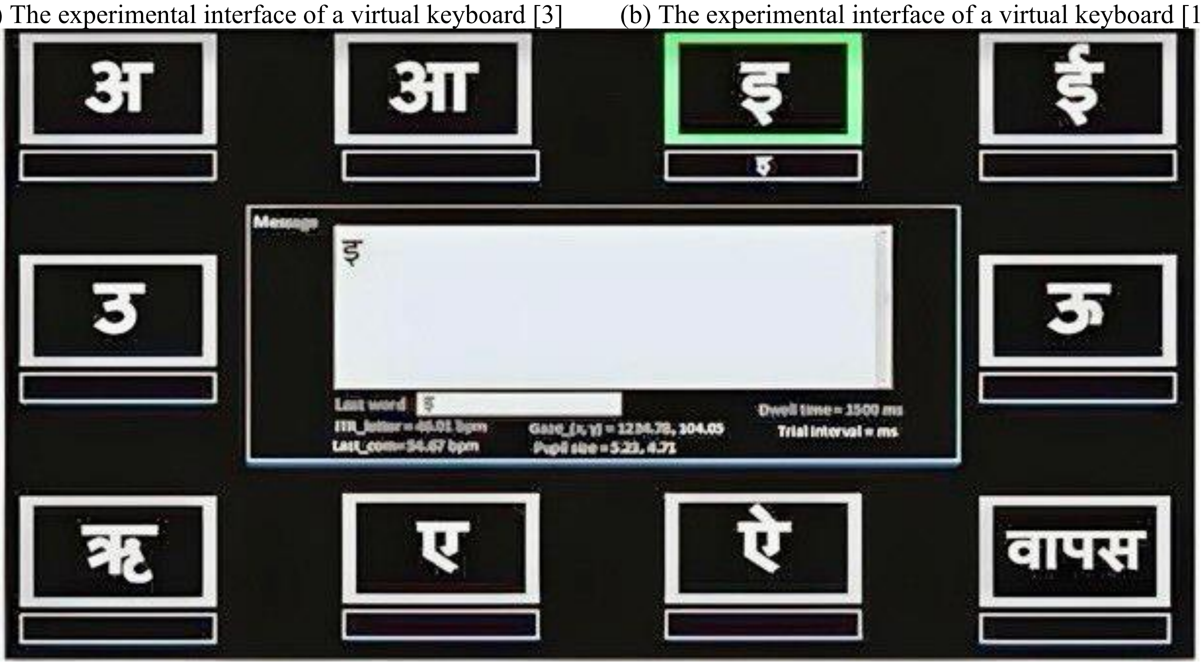
Figure 2. The layout of recent keyboards for the Arabic language



(a) The experimental interface of a virtual keyboard [3]



(b) The experimental interface of a virtual keyboard [15]



(c) The experimental interface of a virtual Hindi keyboard [4]

Figure 3. The tree layout of recent keyboards for most languages

Design considerations for virtual keyboards encompass several factors: the number of symbols per key, variation in key count, the delay time spent on each key, keyboard feedback mechanisms, and text prediction functionality. Key count variation poses a challenge in less-defined virtual keyboards. Feedback mechanisms play a crucial role in informing users of key selection, while text prediction is employed extensively to enhance text input efficiency in virtual keyboard systems.

Recent research predominantly utilizes eye-tracking devices in the development of new keyboard layouts aimed at increasing typing speed. The graphical user interface for virtual keyboards typically comprises two primary sections: the central text typing area and the peripheral area containing various commands (as illustrated in Figure 1).

Virtual keyboards generally consist of 9 to 18 commands, with each rectangular command button occupying approximately 9% to 15% of the GUI window. The configuration of keyboard keys varies, ranging from letters only to combinations of letters, numbers, and special symbols. The arrangement of letters on the keyboard is based on several criteria: frequency of use in the language, random allocation, or specific mathematical calculations as determined by the keyboard's designer.

Recent advancements have been notable in the development of keyboards tailored for the Arabic language, arranging letters based on their frequency and individual weights (refer to Figure 2). Additionally, keyboard keys may feature a single letter or multiple letters, the latter often referred to as the 'tree layout' (as depicted in Figure 3).

Contemporary studies have concentrated on designing virtual keyboards for individuals unable to type using their hands. Consequently, these investigations have focused on creating eye-operated keyboards utilizing AI techniques, as discussed in the Related Works section.

4. RESULTS AND DISCUSSION

4.1 Results

The results of previous research were compared in three aspects. First, the results of the performance measures were compared with the previous results in an accurate numerical manner. Second, there was a comparison in terms of the system's usefulness by taking extra measures. Finally, the participants had a significant influence on the results obtained through the experiments, so it was necessary to compare their features with respect to gender, level of education, age, and other factors.

4.1.1 Performance evaluation

Several performance evaluations of the virtual keyboard were carried out using the following:

(1) Character per minute

The method below was used to compute the number of characters typed per minute for various participants in several trials [1, 5].

$$\text{CPM} = \frac{\text{No. of character}}{\text{Time taken}} \times 60 \quad (1)$$

(2) Word per minute (WPM)

WPM calculates the number of words typed per minute as a measure of text entry rate. Using the following formula, the WPM was determined [1, 5].

$$\text{WPM} = \frac{\text{No. of word}}{\text{Time taken}} \times 60 \quad (2)$$

(3) Total error rate

This is equal to the sum of the corrected error rate (CER) and the not corrected error rate (NCER) [51].

$$\text{TER} = \frac{CER}{NCER} \times 100 \quad (3)$$

(4) Information transfer rate

The ITR is divided and measured at the basic letter level (ITR letter) and command level (ITRcom). Since it is based on the letters that are formed and displayed on the screen, the ITR at the letter level is known as the ITR letter, and at the command level, it is known as the ITRcom due to the fact that it depends on the generated instructions in the GUI. The following is the definition of the ITR [4, 52]:

$$ITRcom = \log_2\left(M_{\text{com}}\right)\frac{N_{\text{com}}}{T} \quad (4)$$

$$ITRletter = \log_2\left(M_{\text{letter}}\right)\frac{N_{\text{letter}}}{T} \quad (5)$$

where, the user's total number of commands needed to type Nletter characters is denoted by the value Ncom. T is the entire amount of time required to create Ncom or type all Nletter.

(5) Keystrokes per character (KSPC)

The average number of keystrokes per character is known as the KSPC [40].

$$KSPC = \frac{\text{No. of keystrokes}}{\text{Character}} \quad (6)$$

4.1.2 System usability scales

To evaluate the usability of virtual keyboards, prior research has predominantly employed two distinct scales:

(1) System Usability Scale (SUS)

The SUS is a ten-item attitude Likert-type measure offering a comprehensive view of users' emotional evaluations. Each item is rated on a five-point scale, with each part capable of receiving a score between 0 and 4. SUS scores range from 0 to 100, with higher scores indicating greater usability. This scale assesses the effectiveness, efficiency, and satisfaction of a system, taking into consideration the context of its usage [4].

(2) NASA Task Load Index (NASA-TLX)

The NASA-TLX is a widely-used, subjective, multimodal assessment tool that measures perceived workload to evaluate the effectiveness and/or other performance characteristics of a task, system, or team. Recognized for its reliability in assessing user workload, the NASA-TLX scale ranges from 0 to 100, with lower scores denoting superior performance. This index was specifically employed to determine the workload experienced by users while utilizing the virtual keyboard application [4].

(3) Participants

Participant characteristics significantly impact trial outcomes. Table 1 in the study juxtaposes participant characteristics with those in previous studies. These characteristics include:

•Both healthy volunteers and individuals with disabilities.

•A typical age range of participants was between 20 and 35 years, although some studies involved a broader age spectrum, including young, middle-aged, and older volunteers.

•Participants comprised employees, general public members, and university students.

•Individuals with normal vision, those wearing glasses, and contact lens users.

•Participants were positioned at a distance of 50 to 80 cm from the computer screen.

•Participants were required to have medium to high English proficiency or native language ability, and similar levels of experience with smartphones and virtual keyboards.

•Usage of eye-tracking communication devices and multimodal input devices, alongside eye-tracking algorithms like Tobii technology.

Table 1. Comparing previous studies of several performance evaluation and system usability scales of the participants

Reference No.	CPM letters/min	WPM	TER %	ITR bits/min	KSPC	SUS score, NASA TLX
[3]	9.48 ± 1.42	----------	57.46	ITRcom 57.46 ± 5.25, ITRletter44.96 ± 5.18	-------	---------
[31]	2-letter 87.5%, 3-letter 70%,	----------	----------	----------	-------	---------
[32]	12.39	----------	35.28%	----------	-------	---------
[54]	----------	1.09	71.9	----------	-------	---------
[6]	36.6±8.4	----------	----------	----------	-------	---------
[15]	8.77±2.90	----------	----------	57.04±14.55	-------	---------
[33]	----------	----------	----------		------	SUS score= 87%, NASA TLX =17
[4]	16.17 ± 5.39	----------	1.31% for soft-switch, 2.63% double tap	96.13 ± 31.03 ITRcom, 89.41 ± 27.74 ITRletter	------	SUS score= 87%, NASA TLX =17
[21]	----------	----------	----------	57.61 ± 14.14 (E), 50.45 ± 13.62 (B), 57.06 ± 22.06 (E), 45.19 ± 15.34 (D)	-------	---------
[40]	----------	15.7	----------	----------	0.946	SUS score =75.4
[39]	----------	15.46	2.68%	----------	-------	---------
[5]	9.50	2.09	20	----------	------	---------
[11]	----------	HumHum=12.55, Hummer= 15.48	----------	----------	-------	---------
[52]	----------	S-Gaze&Finger 10.66 vs. 11.37	S-Gaze&Finger 2.9% vs. 3.54%	----------	-------	---------

Table 2. A comparison of personal characteristics of the participants from previous studies

Reference No.	Healthy	Age	Type	Proficiency
[31]	Random (n)	20-	Normal	Low, medium
[32]	17 non-disabled	Avg. age 36.8	Employee	medium, and high
[6]	10 Healthy	20–35	Normal	Low, medium
[15]	8 healthy	28-49	Normal	Medium
[33]	10 healthy and 10 stroke	21-72	Normal	Low, medium
[4]	24 healthy and disabled	21–32	Normal	Low, medium
[21]	28 Bangla and En., 24 Devanagari and En.	20-	Normal	Low, medium, and high
[39]	12 healthy	21- 3	University students	medium and high
[40]	12 healthy	22-25	university students	medium and high
[11]	12 healthy	22-28	10 students, 2 employees	medium and high
[43]	67 healthy	20–79	Normal	Low, medium
[52]	16 non-disabled	20- 35	Students	low-medium

Table 3. A comparison of technical characteristics of the participants from previous studies

Reference No.	Distance	Vision	Input Devices
[31]	50 cm	Normal	Tobii Eye Tracking
[32]	50 cm	normal, glasses, lenses	eye-tracking
[6]	70 cm	Normal	Tobii 4c
[15]	80 cm	Normal	Eyetribe, Myo armband
[33]	40 cm	Normal and glasses	eye-tracking
[4]	80 cm	15 corrections, 9 glasses	Eye Tribe Aps, Myo armband, a soft-switch
[21]	80 cm	Normal	Tobii Eye Tracking
[39]	65 cm	7 normal, 1glasses,4lenses	SMI REDn tracking
[40]	80 cm	medium or high	Tobii Aps
[11]	75 cm	7 normal, 4glasses,1lenses	eye tracking algorithm
[43]	52 cm	Normal and glasses	Tobii Technology
[52]	45 cm	13 normal, 2glasses,1lenses	S-Gaze&Finger-&AirTap algorithms

4.2 Discussion

The analysis of Table 2 reveals that the 'Characters per Minute' criterion is paramount in assessing the efficacy of virtual keyboard creation techniques, particularly in terms of typing speed. This is closely followed by the 'Information Transfer Rate'. Conversely, many studies prioritize the 'Keystrokes per Character' metric over the 'Total Error Rate', underscoring the importance of understanding error magnitude in these systems.

The fluctuating results in Table 2 can be attributed to the diverse characteristics of the participants. Notably, recent research indicates an upward trend in the 'Characters per Minute' criterion, suggesting that contemporary methods are enhancing typing speed.

Additionally, the metric of 'Words per Minute' is considered secondary to 'Characters per Minute'. This is because the definition of a 'word' varies based on the number of letters it contains, leading to variability in measurement precision.

Recent years have seen the development of system usability scales based on participant feedback, focusing on two key aspects: typing speed and user comfort. The choice of input devices interfacing with the keyboard significantly influences these outcomes, especially in terms of speed and accuracy in key selection.

Table 1 highlights that the factors such as age, health condition, and education level greatly impact results. Optimal outcomes are often observed in participants who are in good health, middle-aged, and highly educated.

Table 3 suggests a preference among researchers for participants with good eyesight, as the use of eyeglasses can adversely affect results. Participation of individuals with disabilities has been limited, primarily due to the complexities and specialized techniques required for their inclusion in such studies.

The employment of eye-tracking equipment demonstrates a direct correlation between the scale of vision and distance and the accuracy of key selection from the virtual keyboard. In contrast, visual and distance parameters are less critical when using alternative input methods like fingers, tongues, or EEG devices.

5. CONCLUSION

This research underscores the imperative need for specialized human-computer interfaces to aid individuals with significant physical disabilities and speech impediments, who are unable to utilize conventional communication methods such as speech or sign language. Adapted commercial products like modified keyboards and joysticks, alongside cutting-edge technologies including brain interfaces and virtual keyboards, are pivotal in fostering independence among disabled individuals.

The development of innovative virtual keyboards plays a crucial role in enhancing the communication abilities of a substantial segment of the disabled population. These keyboards are continuously being refined to improve ease of communication. Key attributes of these interfaces include naturalness in interaction and rapid typing capabilities. Furthermore, the selection of GUI layouts is critical in optimizing the proximity of characters, thereby enhancing typing efficiency.

Evaluating the performance of virtual keyboards is challenging, given its dependency on factors such as user motivation, experiment duration, and the amount of text to be produced. Insights from users with severe disabilities are invaluable in refining these interfaces.

Analysis of previous studies reveals that while eye-tracking devices can expedite typing, their cost is prohibitive for many with disabilities. Consequently, recent research has shifted focus towards eye-tracking techniques and the enhancement of virtual keyboard layouts. It has been observed that alternating between dwell-free and dwell-time staring yields superior results.

Looking ahead, the development of more precise eye-tracking techniques presents a promising avenue. These future methodologies, relying on letter and word prediction as well as phonetic algorithms, hold the potential to minimize user errors and further accelerate typing speed.

REFERENCES

[1] Bharath, M.R.R. (2022). Controlling mouse and virtual keyboard using eye-tracking by computer vision. Journal of Algebraic Statistics, 13(3): 3354-3368.

[2] Ramadhan, Z.A., Alzubaydi, D. (2019). Text detection in natural image by connected component labeling. Al-Mustansiriyah Journal of Science, 30(1): 111–118. https://doi.org/10.23851/mjs.v30i1.531

[3] Tamilselvi, R., Sarguna, R. (2017). Eye tracking based virtual keyboard for disabled people. International Journal of Advanced Research Trends in Engineering and Technology, 4(11): 331-334.

[4] Meena, Y.K., Cecotti, H., Wong-Lin, K., Prasad, G. (2019). Design and evaluation of a time adaptive multimodal virtual keyboard. Journal on Multimodal User Interfaces, 13: 343-361. https://doi.org/10.1007/s12193-019-00293-z

[5] Islam, R., Rahman, S., Sarkar, A. (2021). Computer vision based eye gaze controlled virtual keyboard for people with quadriplegia. In 2021 International Conference on Automation, Control and Mechatronics for Industry 4.0 (ACMI), Rajshahi, Bangladesh, pp. 1-6. https://doi.org/10.1109/ACMI53878.2021.9528213

[6] Lystbæk, M.N., Pfeuffer, K., Grønbæk, J.E.S., Gellersen, H. (2022). Exploring gaze for assisting freehand selection-based text entry in ar. Proceedings of the ACM on Human-Computer Interaction, 6(ETRA): 1-16. https://doi.org/10.1145/3530882

[7] Struijk, L.N.A., Lontis, R. (2017). Comparison of tongue interface with keyboard for control of an assistive robotic arm. In 2017 International Conference on Rehabilitation Robotics (ICORR), London, UK, pp. 925-928. https://doi.org/10.1109/ICORR.2017.8009367

[8] Onsorodi, A.H.H., Korhan, O. (2020). Application of a genetic algorithm to the keyboard layout problem. PloS ONE, 15(1): e0226611. https://doi.org/10.1371/journal.pone.0226611

[9] Alshudukhi, J., Alshaibani, B. (2021). An improved arabic keyboard layout. Journal of Science International, 33(1): 5-15.

[10] Struijk, L.N.A., Bentsen, B., Gaihede, M., Lontis, E.R. (2017). Error-free text typing performance of an inductive intra-oral tongue computer interface for severely disabled individuals. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 25(11): 2094-2104. https://doi.org/10.1109/TNSRE.2017.2706524

[11] Hedeshy, R., Kumar, C., Menges, R., Staab, S. (2021). Hummer: Text entry by gaze and hum. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, Yokohama, Japan, pp. 741. https://doi.org/10.1145/3411764.3445501

[12] Tathe, A., Mondal, A., Shetty, A., Mulla, A., and Kalal, A.N., (2021). A review on gesture recognition based virtual mouse and keyboard. International Journal of Research Publication and Reviews, 3(5): 1363-1365.

[13] Pi, J., Shi, B.E. (2017). Probabilistic adjustment of dwell time for eye typing. In 2017 10th International Conference on Human System Interactions (HSI), Ulsan, Korea (South), pp. 251-257. https://doi.org/10.1109/HSI.2017.8005041

[14] Ahmad, M.B., Raja, M.A., Asif, M.W., Khurshid, K. (2018, May). i-Riter: Machine learning based novel eye tracking and calibration. In 2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), Houston, TX, USA, pp. 1-5. https://doi.org/10.1109/I2MTC.2018.8409587

[15] Cecotti, H., Meena, Y. K., & Prasad, G. (2018, July). A multimodal virtual keyboard using eye-tracking and hand gesture detection. In 2018 40th Annual international conference of the IEEE engineering in medicine and biology society (EMBC), Honolulu, HI, USA, pp. 3330-3333. https://doi.org/10.1109/EMBC.2018.8512909

[16] Hameed, D.H., Mahmood, M.K. (2020). Person identification based on different colour models iris biometric and contourlet transform. Journal of Engineering and Sustainable Development, 24(1): 15-33.

[17] George, A. (2019). Image based eye gaze tracking and its applications. arXiv preprint arXiv:1907.04325.

[18] Jose, A., Thodupunoori, H., Nair, B.B. (2019). A novel traffic sign recognition system combining viola–jones framework and deep learning. Soft Computing and Signal Processing, pp. 507-517. https://doi.org/10.1007/978-981-13-3600-3_48

[19] WiViK, https://www.1q4all.com/wivik.php, Accessed on July 20, 2020.

[20] Hearty Ladder, http://heartyladder.net/xoops/, Accessed on July 20, 2020.

[21] Cecotti, H., Meena, Y.K., Bhushan, B., Dutta, A., Prasad, G. (2019). A multiscript gaze-based assistive virtual keyboard. In 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Berlin, Germany, pp. 1306-1309. https://doi.org/10.1109/EMBC.2019.8856446

[22] Cheat, M., Wongsaisuwan, M. (2018). Eye-swipe typing using integration of dwell-time and dwell-free method. In 2018 15th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), Chiang Rai, Thailand, pp. 205-208. https://doi.org/10.1109/ECTICon.2018.8619868

[23] Kumar, M., Paepcke, A., Winograd, T. (2007). Eyepoint: practical pointing and selection using gaze and keyboard. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, San Jose California, USA, pp. 421-430. https://doi.org/10.1145/1240624.1240692

[24] Huckauf, A., Urbina, M.H. (2008). Gazing with pEYEs: towards a universal input for various applications. In Proceedings of the 2008 Symposium on Eye Tracking Research & Applications, Savannah, Georgia, pp. 51-54. https://doi.org/10.1145/1344471.1344483.

[25] Hansen, D.W., Skovsgaard, H.H., Hansen, J.P., Møllenbach, E. (2008). Noise tolerant selection by gaze-controlled pan and zoom in 3D. In Proceedings of the 2008 Symposium on Eye Tracking Research & applications, Savannah, Georgia, pp. 205-212. https://doi.org/10.1145/1344471.1344521

[26] Panwar, P., Sarcar, S., Samanta, D. (2012). EyeBoard: A fast and accurate eye gaze-based text entry system. In 2012 4th International Conference on Intelligent Human Computer Interaction (IHCI), Kharagpur, India, pp. 1-8. https://doi.org/10.1109/IHCI.2012.6481793

[27] Sarcar, S., Panwar, P. (2013). Eyeboard++ an enhanced eye gaze-based text entry system in Hindi. In Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction, New York, United States, pp. 354-363. https://doi.org/10.1145/2525194.2525304

[28] Khasnobish, A., Gavas, R., Chatterjee, D., Raj, V., & Naitam, S. (2017, March). EyeAssist: A communication aid through gaze tracking for patients with neuro-motor disabilities. In 2017 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops), Kona, HI, USA, pp. 382-387. https://doi.org/10.1109/PERCOMW.2017.7917593

[29] Kurauchi, A., Feng, W., Joshi, A., Morimoto, C., Betke, M. (2016). EyeSwipe: Dwell-free text entry using gaze paths. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose California, USA, pp. 1952-1956. https://doi.org/10.1145/2858036.2858335

[30] Mott, M. E., Williams, S., Wobbrock, J.O., Morris, M.R. (2017). Improving dwell-based gaze typing with dynamic, cascading dwell times. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, New York, USA, pp. 2558-2570. https://doi.org/10.1145/3025453.3025517

[31] Cheat, M., Wongsaisuwan, M. (2017). On-screen swipe keyboard using gaze-based method. International Journal of Science, Engineering and Management (IJSEM), 2(12): 174–179.

[32] Pedrosa, D., Pimentel, M.D.G., Wright, A., Truong, K. N. (2015). Filteryedping: Design challenges and user performance of dwell-free eye typing. ACM Transactions on Accessible Computing (TACCESS), 6(1): 1-37. https://doi.org/10.1145/2724728

[33] Meena, Y.K., Cecotti, H., Wong-Lin, K., Dutta, A., Prasad, G. (2018). Toward optimization of gaze-controlled human–computer interaction: Application to hindi virtual keyboard for stroke patients. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 26(4): 911-922. https://doi.org/10.1109/TNSRE.2018.2814826

[34] Pradeepmon, T.G., Panicker, V.V., Sridharan, R. (2018). Hybrid estimation of distribution algorithms for solving a keyboard layout problem. Journal of Industrial and Production Engineering, 35(6): 352-367. https://doi.org/10.1080/21681015.2018.1508080

[35] Sandnes, F.E., Eika, E., Medola, F.O. (2019). Reducing scanning keyboard input errors with extended start dwell-time. In Proceedings of the International Conferences on Usability & User Experience and Human Factors and Assistive Technology, Orlando, Florida,

USA, pp. 808-817. https://doi.org/10.1007/978-3-319-94947-5_79

[36] Costagliola, G., Raffaele, D.A., De Gregorio, S., De Rosa, M., Fuccella, V., Lupo, D. (2019). Text entry on circular smart watches: The C-QWERTY Layout. Journal of Visual Languages and Sentient Systems, 2019(2): 127-134.

[37] Whittington, P., Dogan, H. (2016). Smartpowerchair: Characterization and usability of a pervasive system of systems. IEEE Transactions on Human-Machine Systems, 47(4): 500-510. https://doi.org/10.1109/THMS.2016.2616288

[38] Herthel, A.B., Subramanian, A. (2020). Optimizing single-finger keyboard layouts on smartphones. Computers & Operations Research, 120: 104947. https://doi.org/10.1016/j.cor.2020.104947

[39] Kumar, C., Hedeshy, R., MacKenzie, I.S., Staab, S. (2020). Tagswipe: Touch assisted gaze swipe for text entry. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, New York, USA, pp. 1-12. https://doi.org/10.1145/3313831.3376317

[40] De Rosa, M., Fuccella, V., Costagliola, G., Adinolfi, G., Ciampi, G., Corsuto, A., Di Sapia, D. (2020). T18: An ambiguous keyboard layout for smartwatches. In 2020 IEEE International Conference on Human-Machine Systems, Rome, Italy, pp. 1-4. https://doi.org/10.1109/ICHMS49158.2020.9209483

[41] Benabid Najjar, A., Al-Wabil, A., Hosny, M., AlRashed, W., Alrubaian, A. (2021). Usability evaluation of optimized single-pointer Arabic keyboards using eye tracking. Advances in Human-Computer Interaction, 2021: 6657155. https://doi.org/10.1155/2021/6657155

[42] Ogata, K., Inoue, S. (2021). Effectiveness of an eye-gaze controlled typing system for the japanese syllabary. International Journal of Innovative Computing, Information and Control, 17(2): 369-381. https://doi.org/10.24507/ijicic.17.02.369

[43] Caligari, M., Giardini, M., Arcolin, I., Godi, M., Corna, S., Colombo, R. (2021). Writing with the eyes: the effect of age on eye-tracking performance in non-disabled adults and a comparison with bimanual typing. Computational Intelligence and Neuroscience, 2021: 9365199. https://doi.org/10.1155/2021/9365199

[44] Mohsin, H., Oday, A. (2019). User authentication secure by randomly cubic spline curve and Blum Blum Shub algorithm. Al-Mustansiriyah Journal of Science, 30(1): 99-104. https://doi.org/10.23851/JMS.v30i1.421

[45] Shen, J., Hu, J., Dudley, J.J., Kristensson, P.O. (2022). Personalization of a mid-air gesture keyboard using multi-objective bayesian optimization. In 2022 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Singapore, Singapore, pp. 702-710. https://doi.org/10.1109/ISMAR55827.2022.00088

[46] Turner, C.J., Chaparro, B.S., Sogaard, I.M., He, J. (2020). The Effects of keyboard layout and size on smartphone typing performance. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 64(1): 985-989. https://doi.org/10.1177/1071181320641237

[47] Nivasch, K., Azaria, A. (2021). A deep genetic method for keyboard layout optimization. In 2021 IEEE 33rd International Conference on Tools with Artificial Intelligence (ICTAI), Washington, DC, USA, pp. 435-441. https://doi.org/10.1109/ICTAI52525.2021.00070

[48] Khan, A., Deb, K. (2023). Optimizing keyboard configuration using single and multi-objective evolutionary algorithms. In Proceedings of the Companion Conference on Genetic and Evolutionary Computation, Lisbon, Portugal, pp. 219-222. https://doi.org/10.1145/3583133.3590580

[49] Kafaee, M., Daviran, E., Taqavi, M. (2022). The QWERTY keyboard from the perspective of the collingridge dilemma: Lessons for co-construction of Human-Technology. AI & SOCIETY. https://doi.org/10.1007/s00146-022-01573-1

[50] Mehta, S., Dadhich, S., Gumber, S., Jadhav Bhatt, A. (2019). Real-time driver drowsiness detection system using eye aspect ratio and eye closure ratio. In Proceedings of international conference on sustainable computing in science, technology and management (SUSCOM), Amity University Rajasthan, Jaipur-India.

[51] Lystbæk, M.N., Pfeuffer, K., Grønbæk, J.E.S., Gellersen, H. (2022). Exploring gaze for assisting freehand selection-based text entry in ar. Proceedings of the ACM on Human-Computer Interaction, 6(ETRA): 141. https://doi.org/10.1145/3530882

[52] Meena, Y.K., Cecotti, H., Wong-Lin, K., Prasad, G. (2016). A novel multimodal gaze-controlled hindi virtual keyboard for disabled users. In 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Budapest, Hungary, pp. 003688-003693. https://doi.org/10.1109/SMC.2016.7844807