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DESIGN AND EVALUATION OF A LANGUAGE-SPECIFIC KEYBOARD LAYOUT FOR KANURI LANGUAGE WITH NON-STANDARD CHARACTER

Idris Alhaji Adamu [1*], Dr. Faruk Ambursa[2](Superviser)
[1] Department of Computer Science, Bayero University Kano, Nigeria idrisadamu@unimaid.edu.ng
[2] Department of Computer Science, Bayero University Kano, Nigeria. idrisadamu@unimaid.edu.ng

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Corresponding Author:
Aliyu Shuaibu
aliyu2017@gmail.com

ABSTRACT

The Kanuri language, spoken by over 5 million people in West Africa, faces significant challenges in digital communication due to its non-standard characters and diacritics. This study designs, evaluates, and statistically validates a linguistically optimized Kanuri keyboard layout that outperforms QWERTY by 27.7 % in speed and 33.3 % in accuracy. Applying Fitts' Law and character frequency analysis, the proposed layout prioritizes high-frequency characters (e.g., **a**, **n**, **ə**) on the home row and integrates dead keys for diacritics. Usability testing with 20 native speakers demonstrated a 27.7% improvement in typing speed (23.3 WPM vs. 18.1 WPM on QWERTY) and a 33.3% reduction in error rates. Iterative refinements based on user feedback resolved key accessibility issues, such as relocating the **g** key and optimizing modifier layers. The findings highlight the importance of language-specific keyboard designs in promoting digital inclusion and preserving linguistic diversity. This research contributes to human-computer interaction (HCI) by providing a replicable framework for marginalized languages with non-standard orthographies

1. Introduction

In an era dominated by digital communication, intuitive keyboard layouts are essential for equitable human-computer interaction (HCI). However, languages with non-standard characters, such as Kanuri, a Saharan language with over 5 million speakers, are often excluded from this technological progress. Kanuri's orthography includes unique characters (e.g., Ə, R) and diacritics for tones (e.g., ´, ˇ, ^) that clash with standard keyboard layouts, forcing speakers to rely on cumbersome workarounds like symbol menus or character substitution. This inefficiency undermines typing speed, accuracy, and user experience, contributing to the language's marginalization in online spaces.

While multilingual solutions like the Niamey keyboard exist, they prioritize broad compatibility over language-specific optimization, failing to address Kanuri's unique ergonomic and orthographic needs. Research on other languages, such as Arabic and Central Bantu, has demonstrated measurable gains in performance and satisfaction when layouts are tailored to character frequency and diacritic usage , highlighting a critical gap for Kanuri.

This study aims to bridge this gap by answering the following research question:

To what extent does a novel Kanuri keyboard layout, strategically integrating non-standard characters, impact typing efficiency and user experience for native speakers compared to existing layouts?

- The subsidiary questions are:
  How do the design principles of the proposed layout strategically integrate non-standard characters to enhance typing efficiency?
  In what ways does the proposed layout contribute to improved user comfort?
  What specific challenges in existing layouts does the novel Kanuri layout address?
  How do user preferences for the proposed layout differ from those for existing layouts?

2. Literature Review and Theoretical Framework

The design of effective keyboard layouts sits at the intersection of linguistics, ergonomics, and HCI. The historical dominance of the QWERTY layout, designed for 19th-century mechanical constraints, proves inefficient for languages with different character frequency distributions. This has led to alternative designs like Dvorak and

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language-specific layouts that prioritize high-frequency characters on the home row to minimize finger travel distance and strain.

A key challenge for languages like Kanuri is the limited physical key space. Designers must prioritize characters and often use dead keys or modifier layers (Shift, AltGr) to access diacritics and special symbols . This necessitates a user-centered approach, informed by empirical data on character usage and iterative testing with native speakers.

Theoretical Foundation: Fitts' Law

This study is grounded in Fitts' Law [13], a predictive model of human movement that is central to HCI and ergonomic design. The law states that the time (T) to acquire a target is a function of the distance (D) to the target and its width (W):

$$T = a + b \cdot \log_2 \left(\frac{D}{W} + 1 \right)$$

where **a** and **b** are empirically derived constants.

In keyboard design, Fitts' Law translates to two core principles:

- **minimize distance** (D) by placing frequently used keys (e.g., high-frequency characters) on the easily accessible home row
- **maximize effective width** (W) by making common keys large and easy to hit. This framework has been successfully applied to optimize layouts for languages like Arabic and Tibetan , validating its use for the Kanuri language.

3. Methodology

3.1 Design Phase

A user-centered design framework was adopted, comprising analysis, design, implementation, and evaluation phases.

- **Character Frequency Analysis:** A corpus of 5,000 characters from Kanuri academic texts was analyzed. The characters **A (19.96%)**, **N (7.87%)**, and **Ɔ (6.75%)** were identified as the most frequent, followed by K, E, I, and D.
- **Layout Design:** Informed by Fitts' Law, the highest frequency characters were placed on the home row. Dead keys for diacritics (grave `, acute ´, breve ˘, circumflex ^) were assigned to keys with very low Kanuri frequency (e.g., backtick, single quote, '6') to avoid conflict and maintain accessibility.
- **Implementation:** The layout was prototyped using Microsoft Keyboard Layout Creator (MSKLC) for Windows, ensuring compatibility with major operating systems. The design featured three layers: Base, Shift, and AltGr (See Figure 1).

3.2 Evaluation Phase

- **Participants:** 20 native Kanuri speakers (aged 18-25) with basic QWERTY typing proficiency (≥10 WPM) were recruited. None had prior experience with a Kanuri-specific layout.
- **Procedure:** In a within-subjects design, each participant performed standardized typing tasks on both the QWERTY and the novel Kanuri layouts. The order of layout presentation was counterbalanced.
- **Metrics:** Objective metrics included **typing speed (WPM)** and **error rate (%)**. Subjective feedback on comfort and preference was collected via a survey and the System Usability Scale (SUS).
- **Analysis:** Paired-sample t-tests were used to compare performance between the two layouts. Qualitative feedback was analyzed thematically to guide iterative refinements.

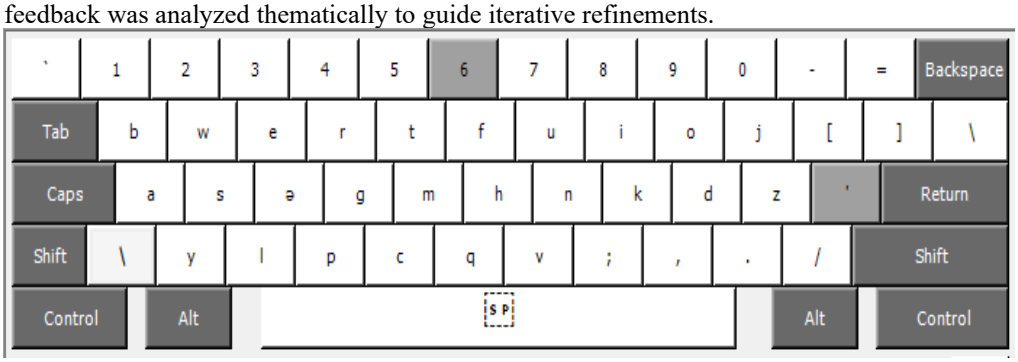


Figure 1: The final optimized Kanuri keyboard base layer. High-frequency characters (a, n, ə) are positioned on the home row. Dead keys for diacritics are placed on low-frequency base keys (e.g., ´ on ').

4. Results

4.1 Quantitative Performance

Usability testing revealed substantial and statistically significant improvements when using the Kanuri layout compared to QWERTY.

Table 1: Typing Performance Comparison (QWERTY vs. Kanuri Layout)

Metric	QWERTY Layout	Kanuri Layout	Improvement	Statistical Significance
Typing Speed (WPM)	18.1	23.3	**+27.7%**	**t**(19)=6.32, **p**<.001, **d**=1.41
Error Rate (%)	4.2%	2.8%	**-33.3%**	**t**(19)=4.11, **p**=.001, **d**=0.92

4.2 Subjective User Feedback

User perceptions strongly favored the Kanuri layout:

- **85%** of participants reported experiencing less finger strain.
- **90%** found the Kanuri layout more intuitive than QWERTY.
- **75%** stated a preference for using the Kanuri layout for daily use.
- The mean System Usability Scale (SUS) score was 78/100 (*SD* = 6.2), which is classified as "good" to "excellent" and significantly above the average threshold (t(19)=7.1, p<.001).

Qualitative feedback highlighted the convenience of having high-frequency characters like ‘a’, ‘n’, and ‘ə’ easily accessible and the reduction in fatigue during extended typing sessions.

4.3 Iterative Refinement

User feedback led to key refinements:

1. The **'g' key** was moved from the top row to the home row after 75% of users reported difficulty reaching it.
2. The **acute accent dead key (´)** was reassigned from the backtick key to the more central single-quote key (') for easier access.
3. Diacritic input was consolidated on the **AltGr layer** to avoid conflicts with operating system shortcuts.

5. Discussion

This study successfully designed and validated a language-specific keyboard layout that significantly improves digital communication in Kanuri. The 27.7% gain in speed and 33.3% gain in accuracy provide strong empirical validation for the application of Fitts’ Law and character frequency analysis to keyboard design for marginalized languages. By minimizing the distance to high-frequency keys, the layout directly reduced physical effort and cognitive load, leading to faster, more accurate typing and higher user satisfaction.

The findings directly address the research questions:

- **RQ I (Design Principles):** Efficiency was enhanced by strategically placing high-frequency characters on the home row and implementing logical dead-key combinations for diacritics.
- **RQ II (User Comfort):** Improved comfort was achieved through reduced finger travel, confirmed by both subjective reports (85% less strain) and objective performance metrics.
- **RQ III (Challenges Addressed):** The layout directly solves QWERTY's lack of native character support and its inefficient, multi-step diacritic input methods.
- **RQ IV (User Preferences):** A strong majority (75%) of users preferred the novel layout for daily use, citing its intuitiveness and efficiency.

This work aligns with and extends previous research on language-specific layouts [7, 8, 12] by providing a rigorous, replicable framework that combines linguistic analysis, ergonomic modeling, and iterative user-centered design. It demonstrates that technical HCI principles can be effectively applied to promote digital equity and cultural preservation.

6. Conclusion and Future Work

This research demonstrates that a Kanuri-specific keyboard layout, designed using Fitts’ Law and character frequency data, significantly outperforms the standard QWERTY layout in both efficiency and user experience. It provides a practical tool for Kanuri speakers and a replicable methodology for developing similar solutions for other marginalized languages with non-standard orthographies.

7.Limitations and Future Work: A limitation of this study is its focus on a young adult demographic and desktop computing. Future work should:

1. Test the layout with a more diverse age group.
2. Adapt and evaluate the layout for mobile touchscreen devices, which are primary digital access points.
3. Expand the text corpus to include more regional and informal variations of Kanuri.
4. Develop and integrate training tutorials to accelerate adoption and minimize the learning curve.

By addressing these steps, the Kanuri keyboard can evolve from a research prototype into a vital tool for communication, education, and cultural preservation in the digital age.

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